Doc

9

X-RAY MANUAL

ETS-LGH File No. 2

COMPILED AND PUBLISHED AT THE
MEDICAL DEPARTMENT
ENLISTED TECHNICIANS SCHOOL
U.S. Army, LETTERMAN GENERAL HOSPITAL
SAN FRANCISCO, CALIF. 1942

FOR THE USE OF STUDENTS.

I. INTRODUCTION

We hope to accomplish in the next three months certain definite objectives, one of these is to give to you a fundamental knowledge of the physics and mechanics of X-Ray and the relationship of this knowledge to the construction and maintenance of X-ray equipment. Also we hope to give you the training which will enable you to become expert X-ray technicians. We want you to be able to take the field equipment, similar to that which we have here, out into the field under any circumstances and take satisfactory, diagnostic X-ray films.

We want you to know the fundamentals of roentgen-therapy so that when called upon in the field to administer a prophylactic or a thereapeutic dosage of X-ray for gas gangrene, in dirty, filthy war wounds, you will be able to respond without fear and with efficiency. We are even optimistic enough to hope that our course will be sufficient to enable you to pass any necessary examination which would qualify you as civilian X-ray technicians.

You have by circumstances or by choice started upon a course which will single you out as a member of a definite profession with a definite purpose, responsibility, and privilege. I speak of your place in the medical department of the army or in a larger sense in the medical profession as a whole. Since you are entering this profession it behooves you to know something of its organization and standards.

Let us consider first your position in the medical department of the army. You know that the medical department has certain basic missions and responsibilities. This is fundamentally the care of the sick and wounded among the army personnel, both in peace time and in combat. This duty of caring for sick and wounded is not without danger. Statistics show us that in the last war casualties in the medical department were second only to those of the infantry. Your duties will call you into the zone of operations and into the area of the combat. (For this reason, discipline is not, as some might indicate, without importance in the medical department.) You must be prepared, however, to perform your duties efficiently in spite of danger and hardship.

Let us consider next your relationship in this medical department to other members of your department. The medical officer who will be in command of your detachment is a doctor. He has spent some eight to ten years of his life after finishing high school in preparing himself to adequately care for sick and injured human beings. You can recognize these medical officers by the fact that the insignia which they wear on their coat lapel, the Caduces, has no qualifying initial. Besides the medical officers in the medical

department we have sanitary officers, denoted by an "S" in the Caduces, dental officers denoted by a "D" in the Caduces, and Medical Administrative officers denoted by a "A" in the Caduces, who are not trained professionally to care for sick and injured but are very essential in the administration and functioning of the Medical department establishment.

Now among the medical officers whom we have mentioned there are two general types, those medical officers who do anything that happens to come along in a pretty good way and other, specialized men who only do two or three things in a very special way. In Civilian life we designate these men as general practitioners or as specialists. Naturally there is a wide variation in the amount of work in the various fields which general practitioners and specialists do. Usually, however, the differentiating point depends upon whether the specialist actually restricts a great majority of his work to one particular field. Today there are many, many branches which men have specialized in. There are outstanding branches of the profession which require specialization. We think of these especially as the surgeon, the eye, ear, nose and throat specialist, the orthopedic specialist, and, - now we are getting close to home, - the radiologist.

The specialty which we find ourselves associated with has three names: radiology, roentgenology, or just plain x-ray. The science of radiology falls easily into two large sub-divisions: that of roentgen-diagnosis and of roentgen-therapy. Roentgen-diagnosis includes all of those procedures by which an attempt is made to diagnose or determine what particular disease or pathology is affecting the patient which you have at hand. Roentgen-therapy on the other hand presupposes an accurate diagnosis and deals only with treatment or therapy needed to correct the pathology of disease.

The two large groups of radiology which we mentioned, therapy and diagnosis have each been divided into two sub-groups: in therapy we have superficial therapy, for infectious types of diseases, and deep-therapy for malignant diseases or cancer. In this course we will consider more the superficial therapy, namely, the therapy for prophylactic and therapeutic treatments of gas gangrene in the field. The sub-divisions mentioned under diagnostic radiology is that of fluoroscopic examination and radiographic examination, or the use of the fluoroscope and the use of the x-ray film. We will consider both of these divisions in this course.

In considering the history of the roentgen-ray and its discoveries it is difficult to determine the first production of x-rays. Many years before the actual discoverey of x-ray in 1895, by William Konrad Roentgen, Geissler had noted the color effects produced by discharging high-voltage electric currents through a tube of low vacuum. It is not unlikely that x-rays were produced at that time. Later on Crooks had noted the succession of changes in a tube as the vacuum was increased until it became so high that a current would no longer pass through. Leonard, by an ingenious experiment, had succeeded in bringing the cathode stream outside of the tube through an aluminum window. These and many, many others had experimented with electrical discharges through vacuum tubes for more than 35 years. There can be no question but that many of these experimenters had actually dealt with x-rays but had not recognized them as a new type of radiation.

Let us consider then, a little about the life of the man who not only produced x-rays, but also realized that he had produced them and studied them so carefully that it was many, many years before we found more about the properties of his rays than he himself had determined. Roentgen was born in Linnet, in Rhennish, Prussia, on March 27, 1845. His early life was spent in a small, rural community and like many of us today he did not like the type of course offered to him in the public schools of those days and he was never considered as outstanding in his elementary work. His primary education was interrupted before its completion by his expulsion from school because of his refusal to divulge the names of his comrades in a childish prank. After this he had some difficulty in obtaining permission to enter other schools. As trivial as this seems, it almost put an end to his future career and resulted in changing the entire course of his life. Finally he was admitted to the Polytechnic School in Munich where he became interested in physics and mathematics. After graduation he held various positions in the field of physics and in 1879 he became the director in the Institute of Physics in the City of Geissen, a position he retained for nine years.

In 1888 he was called to the University of Wortsburg in Bavaria to assume the position of Director of the Physical Institute. It was here that he discovered the x-ray. By experimenting with a closed, evacuated Crookes tube, Roentgen made his discovery. He wrapped his tube in black paper so that no light would come from it. He then coated a piece of cardboard with barium platino-cyanide, a substance known to possess fluorescence and to give off light in the presence of such tubes. He noticed that the substance fluoresced when the tube was energized in spite of the fact that the tube was surrounded with black paper. He also noticed that solid objects placed between the tube and card-

board cast shadows indicating that dense objects stopped the rays. He picked up the cardboard one time, and was surprised to see the image of the bones of his hand on the surface of the cardboard. He realized then that he had discovered one of nature's secrets which would be of much value to humanity. He called the rays "X-rays" because "X" designated the unknown. The designation has remained.

Roentgen's greatness does not rest entirely upon the fact that he discovered X-rays. When many men would have rested upon their laurels, Roentgen considered this as only the beginning and he was not satisfied until, by scientific investigation, he had worked out practically all of the physical properties of X-ray. These basic principals are still the foundation of radiology today. Roentgen had many critics at this time who considered his discovery only a matter of luck, but these critics were soon forgotten and he was made a member of the Munich Academy of Science, a position he held until his death. Most scientists do not live to see their discoveries well developed. Roentgen was an exception to this general rule, as he lived until 1923, and most of the progress in Roentgenology had been made prior to that time.

Since we have called this discussion the "History of Radiology", and by definition "Radiology" includes the study of all types of radiation, it is fitting that we consider Radium as well as Roentgen rays, even though this course deals almost entirely with the latter.

Radium is an element which is found in very small quantities upon this earth and has the peculiar property of spontaneous mutation or change into another element, lead. During this change small particles of energy are emitted which have properties similar to those of Roentgen rays.

Radium was discovered in the year 1898 by Pierre and Marie Curie, working in Paris, France. They were able to isolate Radium from Pitchblende ore (known to contain uranium, a related element) only after many months of tedious work and study. Radium has been useful in medicine and industry and will undoubtedly become even more valuable as additional uses are found for it in the future.

In considering the advancement of radiology we cannot help but consider the advancement made in the equipment of radiology. Soon after the discovery of Roentgen rays a target was introduced into the tube and the cathode stream was focused by a cup shaped disc, which directed the stream onto a small spot on the target, increasing the detail on the X-ray film a great deal. The dangers of exposure to X-ray became known in 1896, and methods of protection came into use. Tubes were enclosed in ray-proof boxes such as lead or lead-glass with small openings for the emission of

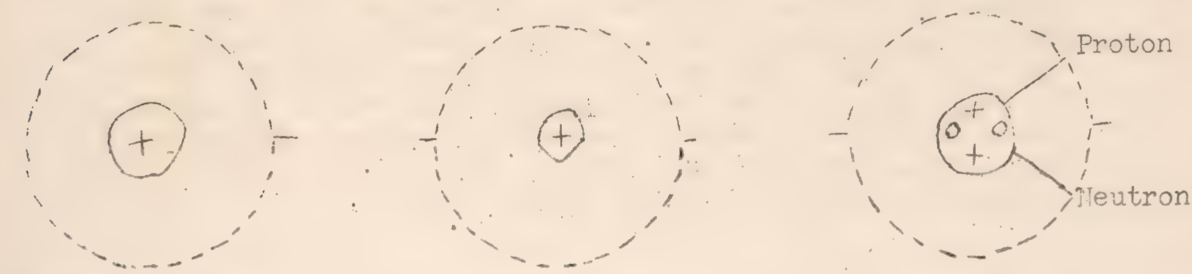
X-rays. Filters came into use and these prevented some of the harmful rays from passing while the useful rays were relatively unaffected. Bigger and better apparatus came into use, water and air-cooled tubes were developed. The demand for speed began and the manufacturers met it so successfully that now a film of the chest can be made in 1/20th of a second and less. Manufacturers of photographic materials, such as film and developing chemicals matched the development of apparatus produced so that none of the gains made in advance of equipment is lost in the processing of the film. Buckey, of Germany devised a grid which greatly increased the value of the film by increasing the sharpness in details of bones and tissues. The stereoscope was developed so that films could be viewed in pairs and a depth perception obtained. The development of shock proof apparatus has greatly minimized the dangers of X-ray examination and has simplified procedure as well as helping a great deal as a time saving factor. The introduction of contrast substances such as barium sulphate and other opaque materials brought into the field the X-ray the examination of the interal organs, including the gastro-intestinal tract, the gall bladder, etc. Since its discovery, X-ray has steadily advanced in importance until it is now the most important single means of arriving at a diagnosis.

Roentgen rays have become of tremendous practical value and are at the present time utilized in industry as well as for diagnosis and treatment of patients. They have also become invaluable tools in numerous scientific investigations as, for instance, in the study of the structure of the atom. The modern theories concerning the structure of the atom have, on the other hand, become very helpful in correlating and systemitizing a number of phenomena, particularly in the field of radiation. Electrical, chemical and radiological phenomena have been bound together in a very simple manner and seem to be logical consequences of the theory. It should therefore be easier to understand the different phenomena related to radiation if a brief outline of the structure of the atom is kept in mind.

An atom can be considered to consist of a relatively heavy nucleus around which one or ore light electrons circle in definite orbits in somewhat the manner as the planets circle around the sun. The electrons are all alike, each one carrying a negative electric charge of -4.803 x 10-10 electrostatic units. This is the smallest amount of electricity that can be obtained. It is of interest to note that all matter is composed of these atoms. It makes no difference whether the matter is wood, iron, water, or air, it is all composed of these very small particles called atoms. The relative weights of these atoms is determined by the number of electrons and positive charges in the nucleus of the atoms. This also determines the physical properties of the substance, since the atoms are all made of identical electrons and positive charges. The only difference between lead and wood is the number of these particles which these atoms contain.

Hydrogen is at room temperature a gas consisting of a tremendous number of molecules (molecules are small aggregations or groups of two or more atoms joined together) which move around with a fairly great velocity. Sometimes one collides with another and then either loses or gains some velocity. One molecule is built up from two atoms and under certain conditions these atoms may become separated. Such a separated atom is the lightest and simplest neutral system we know of, the nucleus of which has an atomic weight of 1.007 and carries an electric charge of plus e, the absolute unit of positive electricity. This nucleus is usually referred to as a proton. Recently a particle referred to as a neutron has been discovered. There are reasons to believe that the neutron is the same as the proton without its positive charge. One electron circles around the nucleus and the negative and positive charges thus balance one another making the system neutral. The electrons can circle only in certain orbits the smallest of which has a radius of .5 x 10 - 8 centimeter. A definite amount of energy is required to pull an electron from an inner orbit into an outer orbit, the same as it required energy to lift

a stone up or away from the earth. The electron may jump from an outer orbit to an inner one and the energy is then given off in the form of radiation. When the electron is in the innermost orbit the system contains the smallest amount of energy and is therefore in the most stable state. If the electron is removed completely, then the remaining proton constitutes a hydrogen ion of charge plus e. If two electrons should at the same time circle around the proton then a hydrogen ion with a charge of minus e would result. Hydrogen has the atomic number of one because the nucleus of its atom has a charge of plus 1 e. It has a positive chemical valency of one because one electron can be relatively easily removed from the neutral atom.



Neutral Hydrogen

Hydrogen with one excess electron H-

Neutral Helium

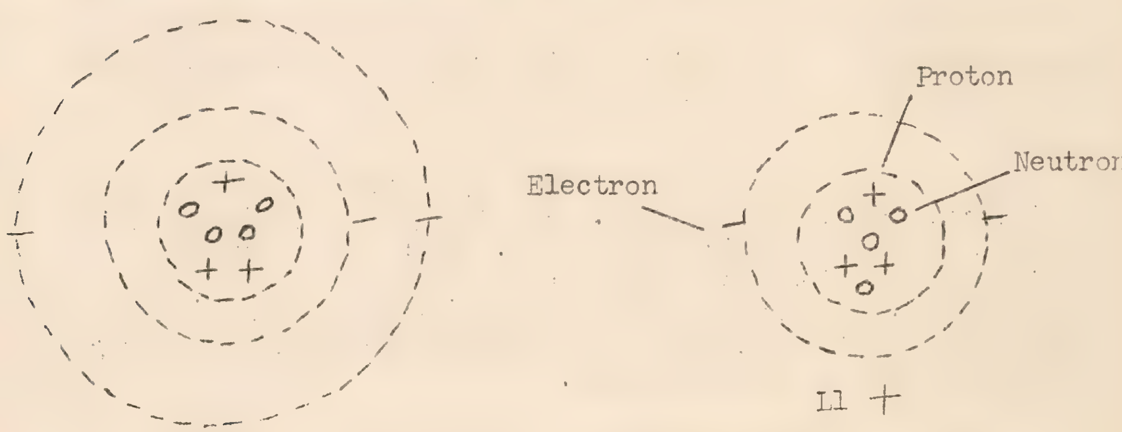
The helium atom consists of a nucleus and two electrons circling around it. The nucleus has a charge of plus 2 e and an atomic weight of 4. When both electrons circle in the innermost orbit or shell the system is in its neutral and most stable state mechanically as well as electrically and it requires a relatively large amount of energy to remove one of the electrons.

A third electron can never be pushed into this shell so that the helium atom is therefore chemically neutral and exists in a free state in the helium gas. In other words, the helium molecule consists of a single atom. One or even both electrons may, however, be forced away to outer shells, or even completely removed. They will, however, be quickly replaced by other electrons and as a consequence radiation will be given off during such a process. The nucleus is minute in size as compared to the atom and has a certain structure, being built up of four protons and two electrons, or according to the latest conception, of two protons and two neutrons. As the nucleus has a charge of plus 2 e the atomic number is 2. The helium nucleus and the alpha-particles emitted by certain radioactive elements are identical.

Lithium of atomic number 3 has a nucleus built up of three protons and four neutrons in the nucleus and three electrons carrying a net charge of plus 3 e. Around this under ordinary conditions, two electrons circle in the innermost shell and one electron in the second shell. The inner shell is thus filled so that the third electron cannot get in but has to stay at a considerably greater distance

away from the nucleus. It can be removed relatively easily and lithium is therefore chemically very active with a positive valence of 1.

The structures of the hydrogen, helium and lithium atoms as here outlined indicate how the atoms of the other elements are built up. Element number 4 has a nucleus with a charge of plus 4 e with four electrons circling around it, etc. The heaviest element, uranium, number 92, has a nucleus with a charge of plus 92e and 92 electrons are distributed in seven shells. The different shells require a different number of electrons before they are completely filled or saturated, thus the first shell requires two electrons and the second, eight electrons. In the atom of the element number 10, Neon, both the first and second shell are filled. The fact that neon is a chemically neutral gas is in agreement with such a picture of its atom. Sodium, number 11, has one electron left over for the third shell, making it a chemically active element of valence one.

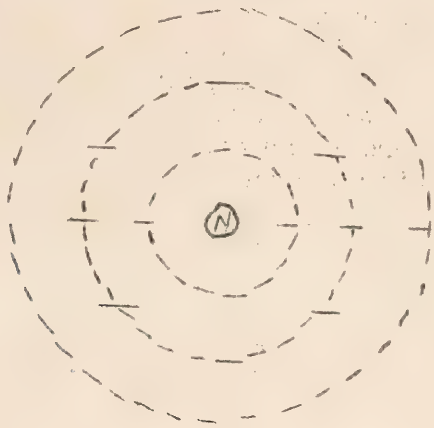


Neutral Lithium

Positive Lithium

This simple outline of the structure of the atom is all that is needed as a foundation for this course. These theories have been developed very much further and also much more in detail but it seems unnecessary to go any further into them now. If a theory of this nature is accepted then it also follows that electricity exists wherever ordinary matter is found; that electrons are available everywhere; that an electric current consists of moving electrons or otherwise charged particles; that radiation can be given off from and absorbed by atoms; that chemical reactions are in part electrical phenomena, etc. A theory is useful as long as it links together in a simple manner, certain experimental findings, and can be used for predictions of other relations without leading to anything that is contradictory to known facts. The atomic theories have been particulary good and helpful but it would, of course, be too presumptive

to believe that we have determined just how an atom is constructed.



Neutral Sodium

ELECTRICITY

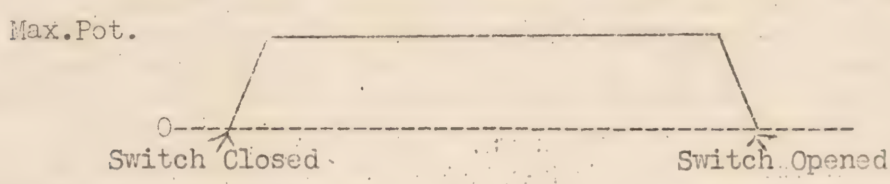
In attempting to discuss this subject the first and probably the most difficult requirement is to give a definition of electricity. This can probably easiest be done, but perhaps not most satisfactorily, by saying that electricity is the flow of electrons over a conductor of electricity. This definition must of necessity be based upon the fact which was mentioned previously that there is a definite attraction between negative and positive particles, therefore, if there is an excess of negative particles at one end of a conductor and an excess of positive particles at the other end of the conductor, the electrons will naturally flow from the negative to the positive particles until an equilibrium is reached.

A conductor is said to be any substance in which the atoms have a weak attraction for the electrons in the atoms. It is well known that metals have a weak attraction for the electrons in the outer orbit of an atom, therefore metals make good conductors. It is for this reason that copper, gold, silver, and other metals are used extensively in electrical circuits. It is of interest to note that the metals are better conductors as they increase in atomic weight, in other words as they have more electrons in the outer orbit.

It was stated that a conductor is a substance which carries a current easily. Conversely, an insulator is a substance which stops the passage of electrons and may be any substance in which the atoms have a strong attraction for the electrons. Non-metals are known to have this strong attraction and are usually used as insulation material. Rubber, porcelain and wood are good examples of insulators.

An electric current is produced by the movement of electrons which produce an electric force which is transmitted from one electron to another along the conductor until the end is reached. This force moves with a speed approximating that of light, 186,300 miles per second, but the electrons themselves may move only a fraction of an inch. This phenomenon can be demonstrated by a roll of pool balls. When the first ball is struck by the cue ball, none of the balls move materially except the last ball in the row. This ball will move across the table with the full force transmitted from the first ball through the other balls much the same as electrons are used to carry the force along a conductor. Electrons can be moved, or an electric current formed, by means of heat, light, friction, chemical action, or magnetism. As has been stated the current is produced when electrons flow through a conductor. The type of current produced when this phenomenan occurs however, may differ under varying circumstances. If the electrons move only in one direction in a steady constant stream it is known as direct current. Direct current can be fixualized as arising from a zero potential

to its maximum potential very rapidly when the circuit is closed and remaining at this maximum potential until the circuit is opened at which time it falls rapidly to a zero potential. It can be graphically represented as follows:



An alternating current is one in which the streams of electrons moves in both directions. A graphic drawing representing alternating current follows the Sine curve and gradually rises from zero potential to is maximum potential then gradually falling again to the zero potential and continuing below the zero potential to a maximum negative potential and then returning to the zero potential.

There is another type of current, sort of a cross between the direct current and the alternating current, which is the result of certain types of rectification which will be discussed later, in which the alternating current is straightened out to go in one direction but instead of having a steady flow of electrons at a maximum potential as in the direct current, there is a pulsating current. This is known as a uni-directional pulsating current and is the type of current usually used in rectified x-ray equipment.

Mechanically Rectified Unidirectional Pulsating Current

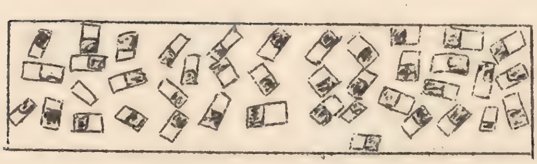
Tube Rectified Unidirectional Pulsating Current

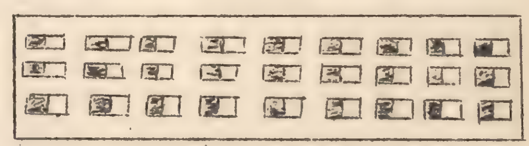
V. MAGNETISM

More than 2000 years ago it was discovered that a certain iron ore called magnetite was able to attract and hold small pieces of iron. This unusual property aroused much interest among the ancients. They regarded magnetite as a curiosity and made little attempt to apply it to any practical purpose. The Chinese, however, used thin pieces of magnetite as a compass. The exact nature of magnetism is unkown. It is believed to be due to an arrangement of the individual atoms whereby their circulating electrons become fixed into uniform positions with relation to their respective nuclei. Each atom might be considered as an individual magnet having two poles, the north and the south pole. The magnet as a whole is considered to be a composite of literally millions of these atomic magnets as shown in the accompanying diagram.

N S

Symbol Representing Molecular Magnet



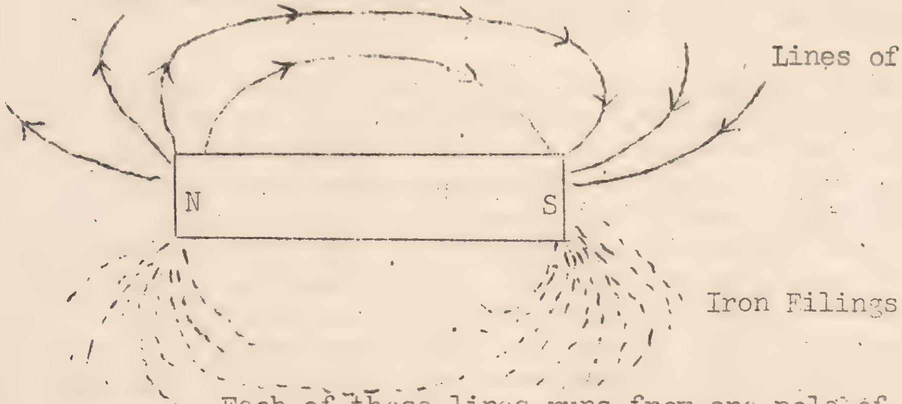
N  S

Unmagnetized Bar

Magnetized Bar

The earth itself is a very large magnet, having a magnetic north pole and a magnetic south pole. The magnetic field of force extending between these poles explains the positioning and alignment of the needle of a compass. The compass is a small, permanent magnet. When the property of magnetism as possessed by this magnetite is not lost by ordinary degrees of impact or the application of moderate temperatures of heat, it is known to be a permanent magnet. There are combinations such as aluminum, nickel, and cobalt, which by themselves do not possess magnetic properties, but which after being influenced by a magnetic field of force develops into very powerful magnets. This combination (trade name "Alnica") maintains magnetic properties indefinitely after becoming magnetized. There are other substances, such as soft iron, which do not possess the properties of magnetism, as they are found in nature, but which develop magnetism when influenced by a strong magnetic field. Such substances are called temporary magnets. Silicon steel is an example of a temporary magnet. It may transiently develop the characteristics of a magnet but loses these qualities when not influenced by a field of force. When the properties of magnetism are maintained by a temporary magnet for some

length of time following the influence of a field of force, there is considered to be a lag of magnetic effect. For certain performances, such as those of a core of a transformer, this lag is detrimental. It is called "Hysceresis." All magnets possess a north and a south pole. The strength of the magnet is concentrated at the pole from which lines of force are said to emerge. The distribution of these lines of force can be determined by putting a large piece of paper over a bar magnet and sprinkle iron filings over the paper. The iron filings will become magnetized by induction. Each of them, will, therefore, act like a tiny compass placed at that point. The filings will be found to arrange themselves in lines, as shown in the drawing.



Each of these lines runs from one pole of the magnet to the other. Scientists have agreed to say that they run from the north pole to the south pole of the magnet. These lines of force together make up the magnetic field of the magnet. Lines of force have the following properties.

1. The north pole of a compass placed at any part of a magnetic field will point in the direction of the line of force that passes through its location.

2. Lines of force never cross each other.

3. Lines of force form closed curves. They leave the north pole of the magnet, enter the south pole, and complete their pass through the magnet.

4. The concentration of the lines of force at any part of a magnetic field determines the strength of the field at that point.

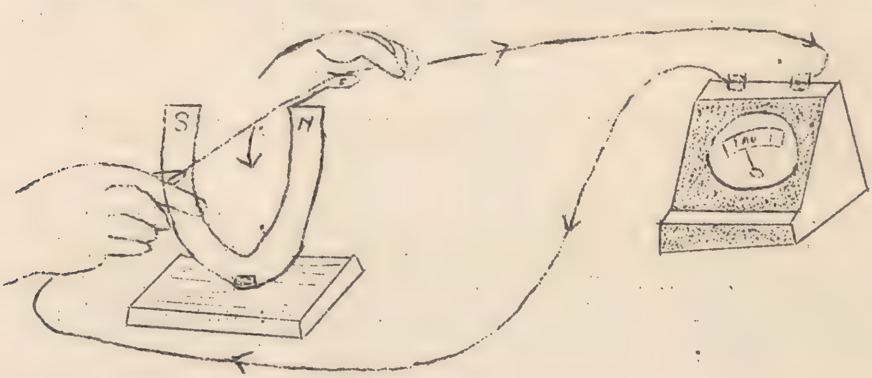
5. Lines of force tend to contract, and thus to shorten their paths.

6. Lines of force repel each other, and thus tend to spread further and further apart as they leave the north pole of a magnet. This gives rise to the law of magnetism which states that like poles repel each other; unlike poles attract each other.

There are various ways of causing electrons to move and this movement of electrons is defined as electricity. There are various ways of inducing an electrical current, such as light, heat, friction, magnetism, etc. To consider the friction we might state that many substances, when rubbed, have the ability to attract like bodies. Thus, a hard rubber fountain pen, when rubbed with a piece of cloth, will pick up small bits of wood, paper, cork, etc. This attraction cannot be due to magnetism because a magnet attracts only magnetic substances such as iron, steel, and nickel. There is another property involved. When a body has this power or ability to attract like objects it is said to "have an electrical charge" or "it is electrified."

If we balance a glass rod, which has been rubbed with silk, on an insulator, and then bring near one end of it another glass rod which has also been rubbed, they repel each other. In a similar way, two hard rubber rods rubbed with flannel repel each other. However, when we bring a rubbed stick of rubber near a rubbed glass rod supported on the needle, they attract each other. It is easy to gather from this in the light of our knowledge of magnetism that when the two glass rods or the two rubber pens repel each other it is undoubtedly because they have the same electrical charge upon them. Therefore, the same law holds true for electrical charges as holds true for magnetism, that is, that like charges repel and that unlike charges attract. Thus, it is seen that there is a very close relationship between magnetism and electricity. Under proper conditions, magnetism will produce an electric current and, vice versa, an electric current will produce magnetic lines of force.

The law of magnetic induction of electrical current states that when magnetic lines of force are cut at right angles by a conductor of electricity there is induced in that conductor an electric current. To study exactly how this current may be induced, the end of a length of wire is connected to the terminals of a sensitive galvanometer. A section of this wire is then held between the poles of a powerful horseshoe magnet, as indicated in the drawing:



2. Induction of Electrical Current

We may now observe that when the wire is rapidly moved downward so that it cuts the lines of force of the magnet, a current is induced and the galvanometer needle is deflected. When the wire is rapidly moved upward between the poles of the magent, the galvanometer needle is again deflected, but this time in the opposite direction. If the wire is held still in the magnetic field, current immediately stops flowing in it and the galvanometer needle returns to zero. Moving the wire parallel to the lines of force of the magnet does not induce a current in it. From these observations, it is evident that a current is induced in a conductor only when the conductor is moved in such a manner as to cut the lines of force of a magnetic field. We may conclude from this observation that when a conductor cuts the lines of force of a magnetic field, an electromotive force is induced in it. It is this induced electromotive force that starts the flow of current in the conductor. The strength of the electromotive force induced in the moving conductor depends upon the number of lines of force cut per second, the greater the number of lines of force cut per second, the greater will be the induced electromotive force. We may therefore increase the electromotive force induced in a conductor by moving the conductor at a greater speed or by providing a stronger magnetic field so that the conductor will cut through a denser concentration of lines of force or by winding the conductor into a coil and using this coil to cut the lines of force of the magnetic field. Since each turn of the coil will cut the lines of force the amount of induced electromotive force will be directly proportional to the number of turns of wire in the coil. Therefore, a coil with five turns will be cutting lines of force five times as fast as a single wire moving in the same field at the same speed. This principle is used in generating electricity in large generators by causing coils of wire wrapped around an armature turned by either water or steam power to be turned through magnetic fields of force generated by electro magnets. This does not form electrons but it puts them through the conductor, much the same as a water pump does not produce water, but merely forces it to move from one place to another.

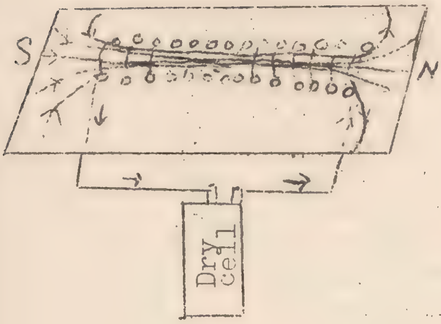
We have seen that when magnetic lines of force are cut at right angles of a conductor of electricity, there is induced in that conductor an electric current. Now let us investigate the converse phenomenon, that is, that when an electric current flows through a conductor of electricity, a magnetic field is induced around the conductor. If we take a single wire and run it through a paper upon which are sprinkled iron filings, as we did before in studying the magnetic lines of force, and we run a current through that conductor we find that these iron filings are distributed in concentric circles around the wire. In other words, there is a magnetic field induced around that conductor which acts upon the iron filings the same way as the lines of force

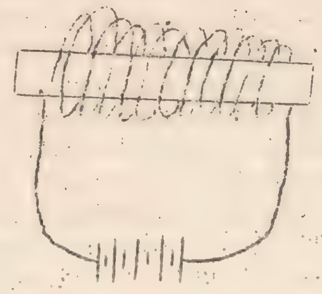
of a permanent magnet did in our previous observations. It is interesting to note that the direction of the lines of force around the conductor have a constant relationship to the direction of the current in the conductor, that is, if the current in the conductor is running in the direction of the thumb of the right hand the lines of force as outlined by the iron filings upon the paper will be found to run in the direction of the finger of the right hand.

If a wire coil is now made with the individual coils of wire running through a paper so that the paper forms a core to the wire and the iron filings are again distributed over the surface of the paper, it will be found that the lines of force assume a different pattern from that in the original single wire conductor experiment. Now, instead of running in concentric circles around each individual wire, the lines of force are concentrated in the center of the coil and run at right angles to the wire, thus, one end of the coil of wire will be the north pole and the other end of the coil will be the south pole. If a soft iron core is now inserted in the center of the coil instead of the paper it will be found that the lines of force will be concentrated in the iron core and the iron core will become a magnet during the time that current flows through the coil. In other words, we now have an electro-magnet. The electro-magnet can be so constructed that it is possible to exert tremendous forces through it. You may have seen them work in scrap iron dumps where many tons of scrap iron are lifted and handled by means of electro-magnets.

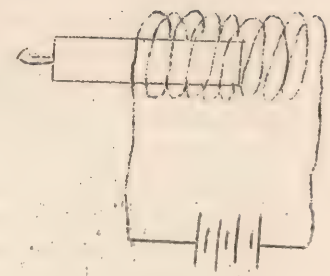
If the electro-magnet is so constructed that the core is fixed in the center of the coils of wire, it is a true electro-magnet. If, however, the iron core is not fixed in the center of the coil, but it is capable of movement back and forth, it functions as an electro-magnet but technically it is known as a solenoid coil. Solenoid coils are used rather extensively in x-ray equipment, for automatic triggers, cut-outs, etc.

4. Induction of Electrical Current.



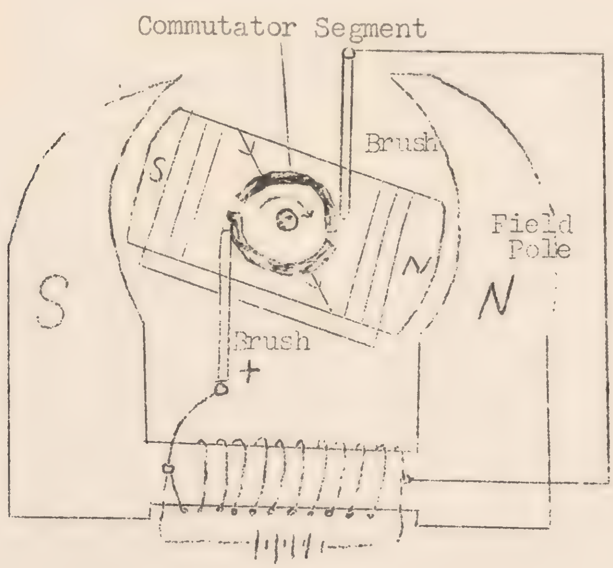


Electromagnet



Solonoid

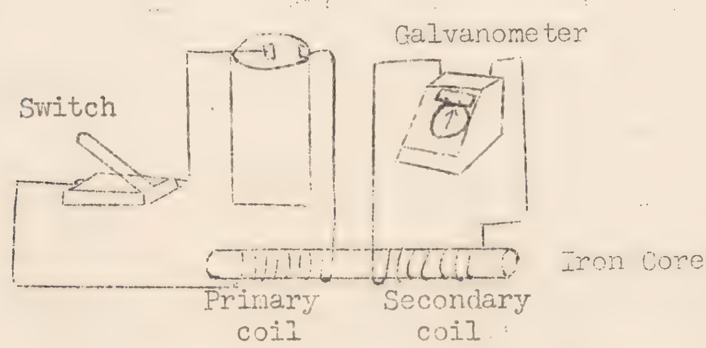
Due to this principle of inducing magnetic lines of force by means of electric current, electrical energy may be converted into mechanical work by means of the electric motor. A simple motor consists of four main parts - the stationary magnetic poles, called field poles. A rotating part, called the armature. A commutator, which is a metal arrangement composed of two segments that are mounted on the axle of the motor and are insulated from each other. Two metal or carbon strips, called brushes, which are mounted in such a way that each is in contact with one-half of the commutator.



In the diagram of the electrical motor, the aranture is simply a bar-electro-magnet mounted on an axle. One end of its coil is connected to each segment of the commutator, which is also mounted on the axle, but insulated from it. Current enters the armature at the brush marked <u>plus</u>, passes around the armature coil, and then returns to the battery through the brush marked <u>minus</u>. When the

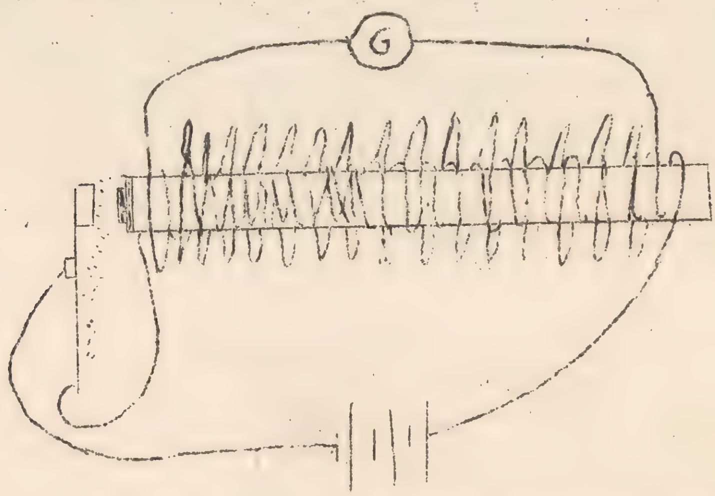
current flows through the armature, its right end becomes a north pole and its left end a south pole. The repulsion between each like armature pole and the field pole causes the armature to make a half turn. If the current continued to flow in the same direction, the armature would cease to rotate at this point. However, at the very moment that the armature has completed this half turn, the segments of its commutator change brushes, thus reversing the direction of the current in the armature and therefore its poles. Again the right end of the armature becomes a north pole and its left end a south pole, and again the repulsion between each like armature pole and field pole causes the armature to make a half turn. This process continues over and over again and keeps the armature turning steadily in one direction.

In previous chapters we have demonstrated how when an electric current flows through a conductor wrapped around a soft iron core the magnetic lines of force are concentrated in that core. We found that this was a basis for the electro-magnet. If this straight core, which we have observed in electro-magnets were bent so as to form a square and the ends joined together, we would find that the magnetic lines of force would still be concentrated in the core and that the lines of force would run around the square in a circular motion. Now let us consider an electro-magnet with a long coil extending out beyond the windings which are necessary for the electro-magnet and around this extension is wound a secondary coil which is in series with the galvanometer. We have then, a switch, a battery, a primary coil wound around an iron core, a secondary coil wound around the iron core in circuit with a galvanometer as is shown in the accompanying diagram:



As the switch is closed in this circuit, current will flow through the primary coils and induce in the iron core magnetic lines of force. These magnetic lines of force will be cut by the windings of the secondary coil on the extension of the iron core and a current will be induced in the secondary circuit as indicated by the deflection of the needle in the galvanometer. We notice now, however, that as the switch remains closed the galvanometer needle swings back to the zero position indicating that no further current flows through the galvanometer because the lines of magnetic force are established and are not being cut by the windings on the secondary coil. The switch is now opened again and the current stops flowing through the primary coil. This allows the magnetic lines of force in the iron core to disintegrate which has the same effect as did the windings on the secondary coil cutting the lines of force as they were being formed, in other words, when the switch is opened and the magnetic lines of force disintegrate, there is another spurt of current through the secondary windings as indicated by a deflection of the needle on the galvanometer. This indicates then, that at the moment of opening and closing the

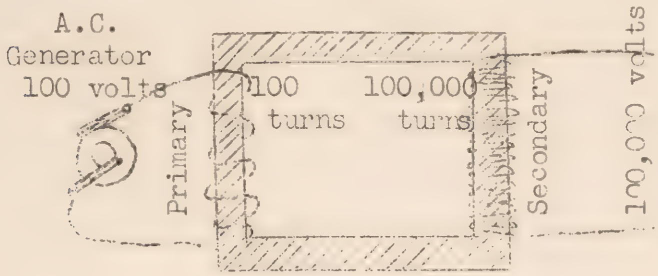
switch in the primary circuit a current is induced in the secondary current circuit. There is no current induced in the secondary coil however, as long as the electrons continue to flow uninterrupted into the primary coils. After this experiment it takes no great mental deduction to realize that in order to obtain any sort of constant current in the secondary coil we must by some means close and open the switch in the primary circuit very rapidly. An ingenious device for accomplishing this has been arranged in the following diagram. This is called an induction coil.



At one stage in the development of x-ray the induction coil was used in the x-ray machine to provide a high tension current for the x-ray tube. This was found to be unsatisfactory however, because when milliamperage values of over 50 milliamps were used the automatic switch or the make and break would burn out from the spark jumping across at the make and break. When this method failed another method had to be developed. This method turned out to be the x-ray transformer. The x-ray transformer functions nearly the same as the induction coil but it uses alternating current for its make and break. You will remember that when we discussed currents we found that the ordinary 60 cycle alternating current came to an abrupt and complete stop two times for every cycle or once for every phase, which is 120 times per second. This provides a rapid and efficient make and break 120 times per second without the accompanying disadvantage of the spark or arching across the mechanical make and break switch.

The x-ray transformer is usually constructed with a square laminated soft iron core. Around one arm of the core the primary windings, with large low-resistance wire is found. Either outside of this primary winding, well insulated, or around the opposite arm of the core, the secondary windings are found made of fine wire with many, many

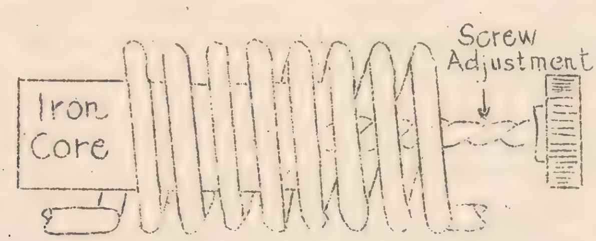
turns as is indicated in the accompanying diagram:



When an alternating current is passed through this primary coil, it sets up an alternating magnetic field inside the coil. This field passes through the soft iron core and sweeps back and forth into the secondary coil. An alternating electromotive force is thus induced in the secondary coil. The magnitude of the secondary electromotive force depends upon the electromotive force applied to the primary and the number of turns on the primary as compared to the number of turns on the secondary coil. To express this relationship mathematically we would say that the primary voltage is to the secondary voltage as the number of turns on the primary coil is to the number of secondary turns on the secondary windings of the coil. It must always be borne in mind that transformation of energy, either mechanical or electrical, is accomplished only at the expense of some of the energy. Therefore, even with the most efficient of transformers some energy is lost in the transformation. Also we must remember that according to the law of the conservation of energy, by merely putting the current through this transformer, we do not create any energy. We merely change its form. In other words, as the voltage is directly raised as the number of turns in the secondary coil is increased over the turns in the primary, so the amperage is directly opposed to this, that is, it is inversely proportional to the number of turns in the secondary over the primary so that as the voltage is raised in the secondary windings of the x-ray transformer the amperage is equally and proportionately dropped.

When we refer to the x-ray transformer we specifically mean the transformer which steps the voltage up from the line current of 100 or 200 volts to the necessary high potential of 100,000 or 200,000 volts necessary to produce x-rays. This does not mean, however, that the x-ray transformer is the only type of transformer. Two other types are the step-down or Coolidge transformer used in the filament circuit which has more windings in the primary than it does in the secondary coil, and the insulating transformer which has an equal number of windings in the primary and secondary coils. The insulating transformer is not used in x-ray equipment, but is useful in protecting long distance power lines from electrical storms.

In order to make easier an understanding of the autotransformer it is best to discuss the principle involved in the simple choke coil, since this same principle is the main functioning principle of the autotransformer. If the two wires of an electrical circuit, such as ordinary house current, come in contact with each other there is an immediate and profuse demonstration of electrical 'fireworks'. This is called a 'short'. However, this same current can be connected to a coil of wire without this disastrous shorting effect. The reason for this is the principle of the choke coil. It has been stated that when current is passed through a coil of wire there is built up about that coil a magnetic field of force made up of many lines of force. It is also a fact that when such lines of force cut across a coil of wire an electric current is induced in that coil. In the case at hand the very coil that produces the line of force is itself, invaded by those lines, which induce a current in the coil. Thus we have the two previously stated principles in operation within the one coil; namely the building up of a field of force about a coil carrying a current, and the induction of a current in a coil when its turns cut the path of a field of force. This induced current flows in the opposite direction from the current coming into the coil and pushes against it thus choking off its flow. In other words the induced current chokes back the flow of incoming current. This is called back electromotive force, or back E. M. F. Such a choke coil must, of course, have a sufficient number of turns of wire of the proper size in order for the self induction to be of sufficient magnitude to almost entirely suppress or choke the line voltage coming to the coil. Self induction is greatly increased by presence of a soft iron core and in many choke coils this core is adjustable, in which case they are called variable choke coils. (See diagram).



VARIABLE CHOKE COIL

In the autotransformer this choking effect is made use of as a means of voltage control. As in the choke coil, there is a coil of wire, composed of several hundred turns, wound around a soft iron core. In this coil are found the same two circuits, the primary circuit composed of the electrons

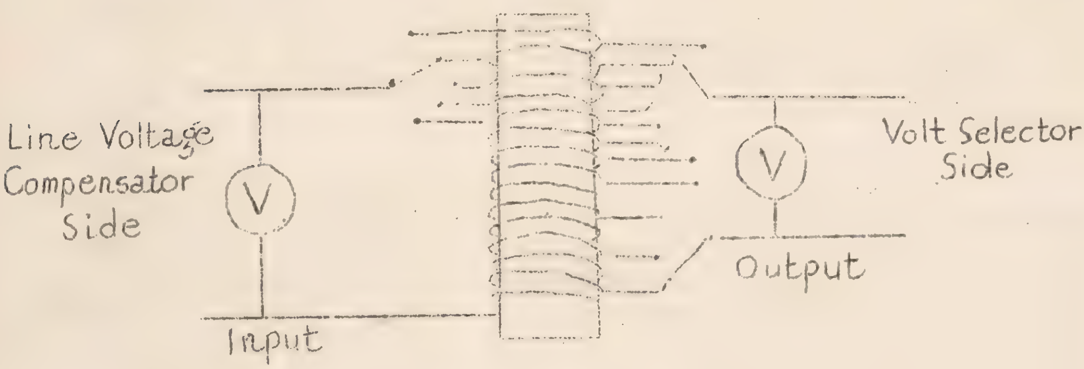
passing through the coil from the line supply, and the secondary circuit composed of the electron flow produced by self induction. The secondary circuit is the back electromotive force choking the line current as it tries to enter the coil. If a wire is attached to one point of the coil (tapped) and a second wire attached to another point anywhere on the coil, there would be available in these leads current, a sum of the induced current of each turn of the coil lying between the two leads. If one lead was moved to a point which would include twice the number of turns, then twice the quantity of induced current would be available.

Actually the coil of an autotransformer is tapped in many places and the taps are divided into three groups, each group being attached to a tap switch. One group is so connected to the coil that many turns of the coil lie between one lead and the next. This tap switch then is labeled 'Major Selector' and each tap makes a change of perhaps 10 or 20 volts in the output. A second group of leads are connected so that only a few turns of the coil are tapped by each lead and its tap switch is labeled 'Minor Selector'. Each tap of this group may only change the output by 1 or 2 volts. The output of the Major and Minor selectors together form the total output of the autotransformer. The third group of leads are connected with a few turns between leads. The central point of the tap switch to which these leads are connected receives one side of the incoming current and by means of the switch (tap selector) the number of turns of the transformer core, which receive the line voltage, can be increased or decreased. This switch is labeled 'Line Compensator'.

To make clear what effect the line compensator switch has on the output of the autotransformer, as well as other points of operation, consider the following example. If an autotransformer has 110 turns of wire and was supplied by a line voltage of 110 volts then each turn of the coil would receive, as its share, 1 volt. That 1 volt per turn would create a magnetic field of given magnitude which would in turn cause an induced current of given strength - namely 1 volt per turn, theoretically. If the Major taps are 10 turns apart then each tap will represent an induced current of 10 volts and if each tap of the Minor switch includes only 1 turn of wire, each tap will have an induced current of 1 volt. Now if the line voltage should drop to 100 volts the whole performance of the transformer would be altered. The 100 volts delivered to 110 turns means that each turn receives less than 1 volt and consequently each turn will induce less than 1 volt. To 'compensate' for this the 'Line Compensator' switch is so adjusted that the new voltage will be delivered to only 100 turns of the coil. In this way the original ratio of 1 volt per turn will be reestablished.

Choke Coil and Autotransformer.

The one important fact about an autotransformer is that it can regulate the voltage and at the same time allow any amount of current (amperage) to pass. In this it differs from all other types of transformers for in the ordinary transformer a decrease in voltage results in a corresponding increase in amperage. From this standpoint the autotransformer is almost indispensable since it is necessary to limit the voltage quite accurately and still have enough amperage flow to produce a small amount of x-rays or a large amount.



Since the tube of an x-ray machine is the only part which produces x-rays and since x-rays are the center of our study in this course, it follows that a thorough understanding of it's construction as well as it's function is most important.

The discovery of x-rays in 1895 by Roentgen was accomplished with the use of a tube, the exact kind seemingly in dispute among the authors. Some say the experiments were made on a Hittorf tube and some insist they were made with the use of a Crookes tube; in either case the difference would not be great. The essential point is that the tube used was a glass bulb which contained a partial vacuum. Such tubes are spoken of today as 'gas' tubes in as much as they contained a small amount of air (gas) when ready for use. This type of tube was used for several decades following the discovery of x-rays.

The main objection to these partially evacuated tubes was that they were not consistent in performance. This was due to the fact that the resistance which existed between the terminals within the tube varied according to the degree of ionization of the gas contained. Conduction of electrons from one electrode (sealed into the wall of the tube near one end) to the other electrode (similarly sealed into the tube near the other end) took place as soon as ionization was produced because of the potentials (negative at one electrode, positive at the other) delivered at the two terminals from some high voltage source. Ionization is that process by which a substance is broken up into its positive and negative components and which renders the substance a conductor of electricity.

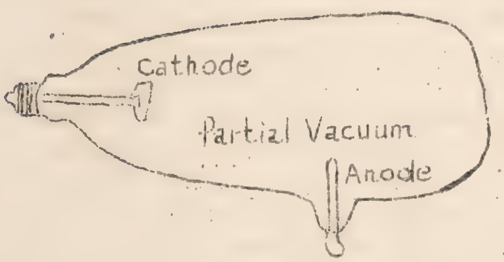
In 1912, a man by the name of Coolidge invoked two important principles which even today are used in the construction of an x-ray tube. These principles include a complete vacuum and provision for thermionic control of current flow (between the two electrodes). A perfect vacuum offers completed resistance to the flow of electrons and modern tubes are as completely evacuated as man can accomplish. Even the metal parts which are to be included within the tube are degassed. When using these tubes the resistance of this vacuum is overcome by heating one of the terminals, the cathode, for with a certain quantity of heat applied to a conductor (about 500° Centigrade in the case of Tungsten), electrons will move out beyond the limits of the conductor. Tungsten was selected for this purpose because of its very high melting point. To provide for its heating, the tungsten was drawn to wirelike dimensions, as in the case of modern electric lamps, and a separate heating circuit was supplied, (The filament circuit). It is completed through the filament itself without involving the target or anode terminal of the tube at all. As the electrons are displaced from the cathode (filament) they are drawn across to the anode structure

(the target) because of the high positive potential being supplied to that structure. (Remember that electrons are negatively charged particles and therefore will be attracted by positive charges).

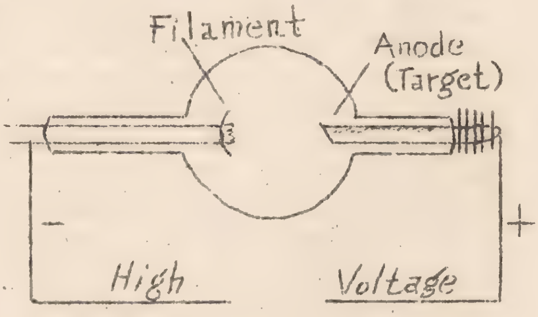
Each one of these electrons given off from the hot filament and accelerated to the target by the high voltage, possesses energy, and of the total energy passing across the tube (tube current) about 99.5% is transformed into heat at the target and about 0.5% is converted into x-rays. The choice of material to be used as an x-ray target depends upon the atomic weight and the melting point of a metal and again Tungsten heads the list, having an atomic weight of 74 and a melting point of about 3400° Centigrade.

In the sketch below the features of a modern, as well as an old style x-ray tube are shown. The complete circuit of the filament is not shown as it will be discussed in a later lesson, however the two lines carrying that current are shown entering the tube through the cathode structure to the tungsten filament. Also connected to one of the filament wires is another wire which comes from the high voltage transformer. The other lead from the high voltage transformer is connected to the anode structure. The lead to the anode, target, side of the tube is the positive wire when unidrectional current is used.

Old Style Gas Tube



Coolidge Tube



In the operation of an x-ray tube three conditions must be fulfilled in order to produce x-rays; (1) electrons must be set free from the filament, (2) these electrons must be set in rapid motion toward the target, (3) they must be stopped suddenly. As has been stated each electron possesses a certain amount of energy, the amount varying with the voltage applied, the greater the voltage the greater the energy. This energy is expended, when the electron strikes the target, in two ways, namely heat and x-ray.

3. X-Ray Tubes

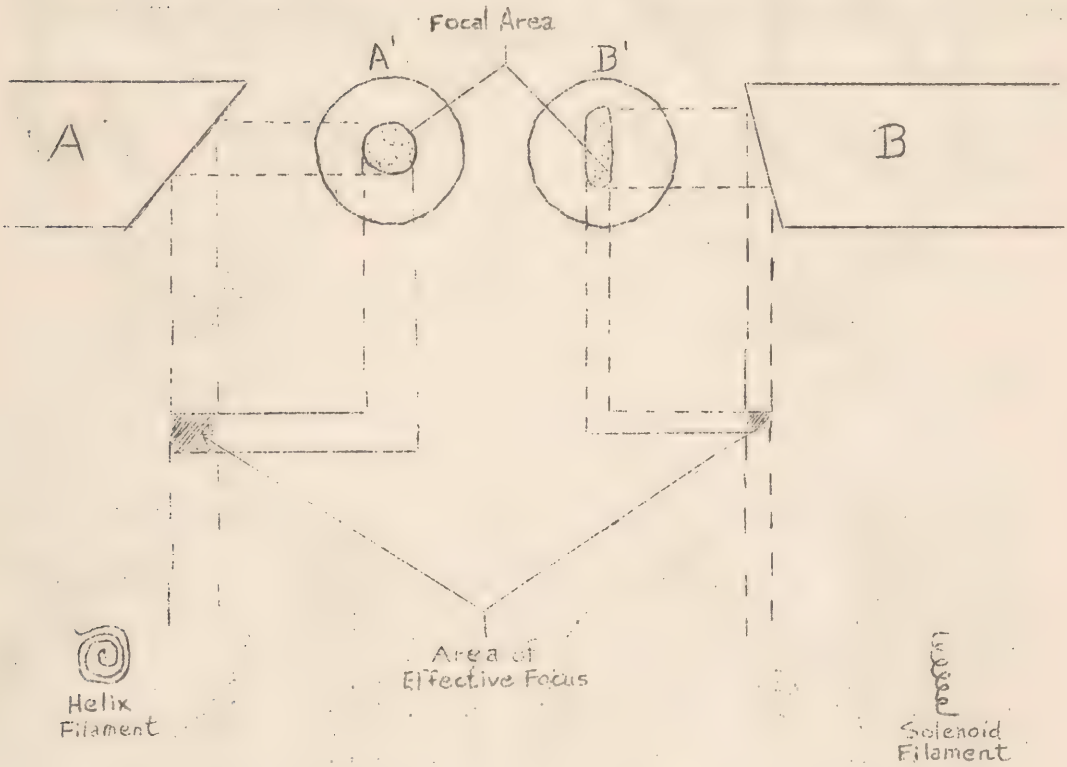
When the electrons strike the target of the x-ray tube some strike electrons that are circulating in the orbits of the atoms of the target and in this way their energy is used up in displacing the electron so struck. When this displaced electron drops back into its orbit it gives up the energy it possesses in the form of radiant energy or X-RAYS. (Review The Atomic Theory). Since it requires a greater amount of energy to displace electrons from each succeeding inner ring or orbit, it follows that when greater amounts of energy are imparted to the bombarding electrons (those from the filament) they will be able to displace electrons from the deeper orbits of the target atom which then will release more radiant energy when they fall back into their orbits. This increase of energy takes the form of SHORTER wave lengths of x-rays, and the shorter the x-ray the more penetrating power it has. Therefore kilovoltage has to do with penetration, or QUALITY of x-ray.

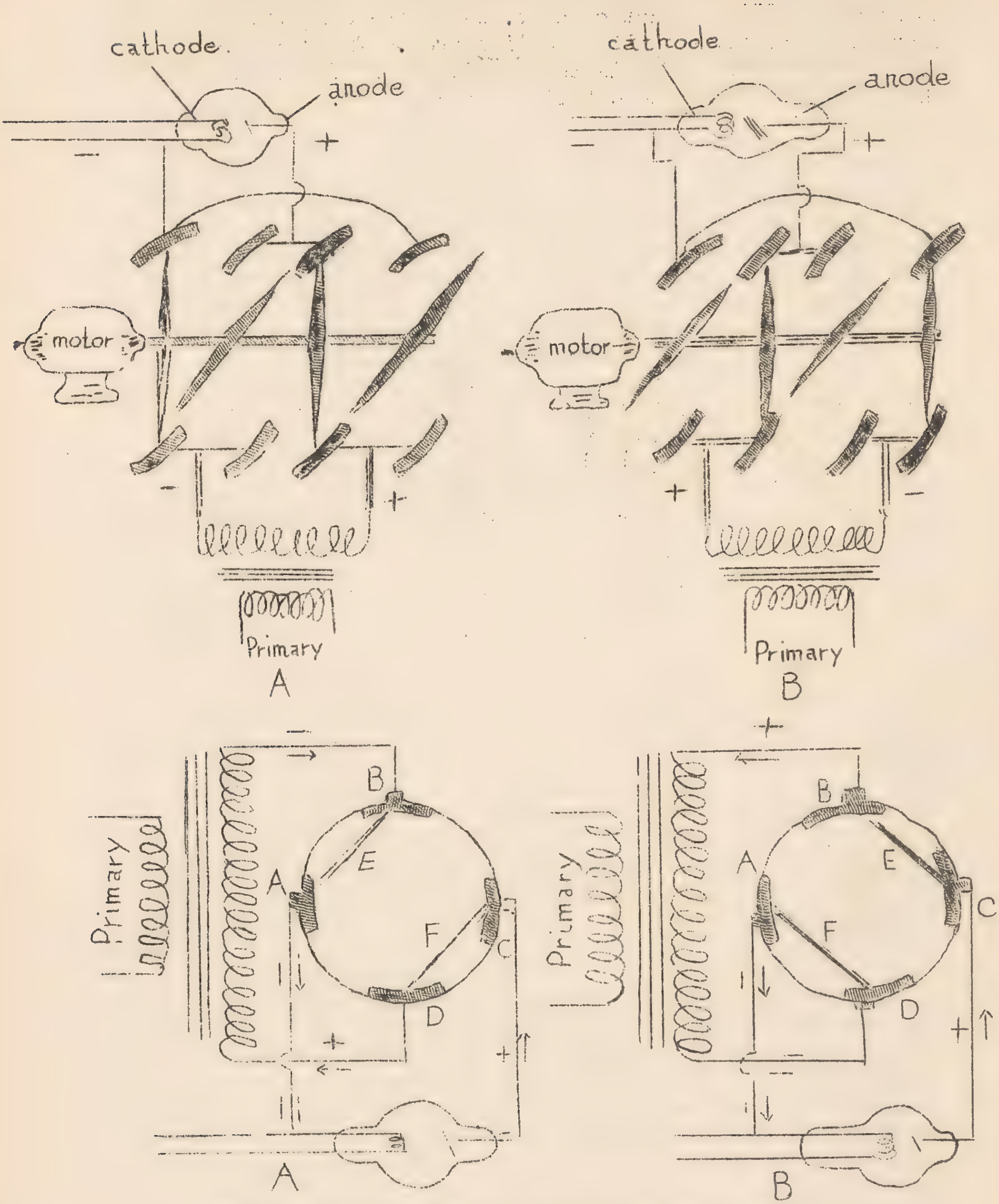
The QUANTITY of x-ray produced depends upon the amount of heat applied to the filament. Heat is the factor that causes the release of electrons from the filament, and the more heat the more electrons are released, therefore the greater number which will bombard the target and the more x-ray produced in a given time. Since more than 99% of the total energy passing through the tube produces heat; the more x-ray produced in a given time the more heat is produced on the target. This heat is the limiting factor in x-ray exposure as far as the tube is concerned.

The electron stream from the cathode is directed toward, and concentrated on, a given area of the tungsten target known as the focal area. The size of this area determines the capacity of the tube, for the smaller the area into which a given quantity of electrons are focused the more intense the heat in that area. The size of this focal area also determines, to some extent, the quality of the radiograph particularly with regard to detail; the smaller the area the sharper and better the detail. In other words to obtain greater tube capacity one must sacrifice detail. Originally this was compensated for by having two or more tubes with varying sizes of focal areas and using the tube with the smallest focal area that would tolerate the exposure for the particular part in question. In the more modern tubes two or more filaments are built into the cathode structure each one focusing its electron stream on the target and each covering a different size area. By means of a switch on the end of the tube the proper size of area can be selected, thus eliminating the changing of tubes.

An innovation of recent years is the line focus principle advanced by Benson, in which the filament takes the form of a solenoid instead of the helix type of filament in the original Coolidge tube. In this way the electron stream is distributed on a focal area which is a narrow band, instead of a round focal area as in the older tubes. The accompanying diagram will show that although the actual area of bombardment of the round spot

A' and the line spot B' are about equal and would thus be able to stand the same amount of heat, while the effective area of focus is much smaller with the line area. The size of the area of effective focus effects the detail of any film; the smaller the area the better the detail and vice versa.





Mechanical rectifier using rectifying disc
A - First phase of cycle
B - Second phase of cycle
(disc rotated by synchronous motor at 1800 RPM)

2. Rectification

The high voltage transformer delivers alternating current. If the terminals of the high voltage transformers were connected to the target and the filament of a roentgen-ray tube respectively, the target would be alternately positive and negative. This means that half the time the target is positive, during which period electrons are attracted from the hot filament, producing roentgen rays at the target. During the other half period the filament is positive and the target is negative, which means that the target is repelling the electrons from the filament. If the target is raised to a temperature sufficiently high to give off electrons (about 500° C.), then electrons will be accelerated from the target to the filament. These electrons will strike the glass and soon raise the temperature sufficiently to crack the glass. The self-rectifying x-ray equipment operates as described.

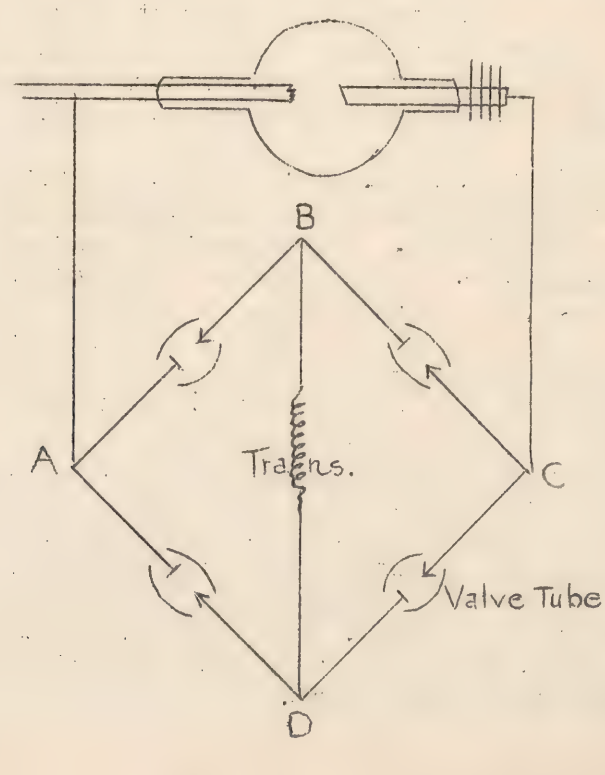
If the target of the x-ray tube can always be maintained positive, then there will be a stream of electrons possible in only one direction, and that from the hot filament to the target. This can be accomplished in at least two ways; by the use of valve tubes, and by means of a mechanical rectifier.

Mechanical Rectification: The current from the high voltage transformer is connected to the terminals of the rectifier. This consists of two conducting arms attached to a shaft that is propelled by a synchronous motor. Such a motor is so constructed as to run in synchronism with the cyclic changes of the alternating current driving the motor. Since the same current is used to run the motor as enters the transformers there are the same number of cyclic changes per second. If, then, the conducting arms are permanently set on the shaft of the synchronous motor in a position to rectify the crest of the wave to get the highest average voltage, the arms will continue to rectify in this position unless changed by a mechanical force or by wear. The operation of such a unit is shown by the accompanying diagrams A and B.

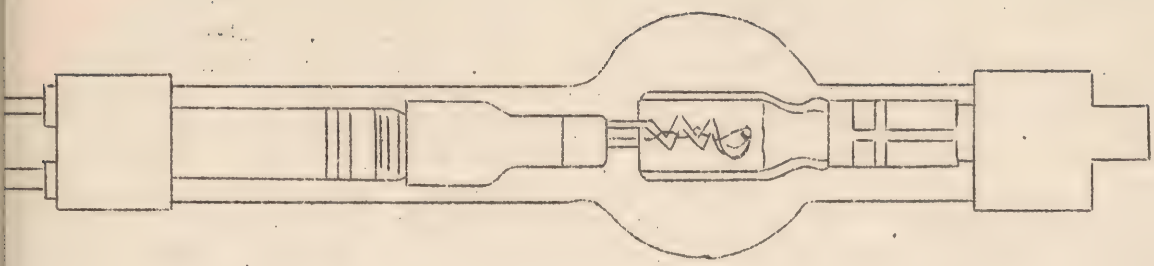
The points A, B, C, D, are fixed contact points supported by an immovable framework usually attached to the top of the transformer case. The conducting arms are labeled E, and F. In diagram A the side of the transformer connected to A is negative. The current passes over arm E to contact B, thence to the filament of the tube. The return of the circuit from the target is connected to contact point C where the current is carried by Arm F to contact D from where it goes to the positive side of the transformer to complete the circuit. Note that the filament is negative and the anode positive. Remember, too, that the arms E and F are constantly revolving and that by the time the alternation has occurred these arms will have moved around to the position shown in diagram B. Here again the current is routed to again deliver negative to the filament and positive to the target. This type of rectification has been largely outmoded by the new valve tube principle but many mechanical units are still in service.

<u>Valve Tube Rectification</u>: Valve tubes are a modification of the Coolidge x-ray tube. They permit current to pass in one direction only, since like the x-ray tube, they have a hot filament and a cool anode (plate) and electrons can only pass from hot to cold electrodes. Their resistance is low as compared to an x-ray tube and when properly used no x-rays are emitted from them. Each valve tube has its own filament transformer. The valve tubes may be arranged in the high tension circuit in many ways, depending on the type of apparatus and the judgment of the manufacturer. They may be used in combinations of one, two, or four. One method of rectification with four tubes is shown in the diagram below. When the alternation is from the transformer to B, it cannot go to C as the valve tube does not permit; it must go from B to A, then through the x-ray tube to C. At C there are two possible paths: to B or to D. The impulse cannot go back to B, as B is at the same potential level as C; it must go to D, thence to the transformer, completing the circuit. When the opposite alternation comes along, the path is from D to A to tube to C to B and back to the transformer. It may be noted that when four valve tubes are used, no impulse is suppressed and the result is <u>full wave rectification</u>.

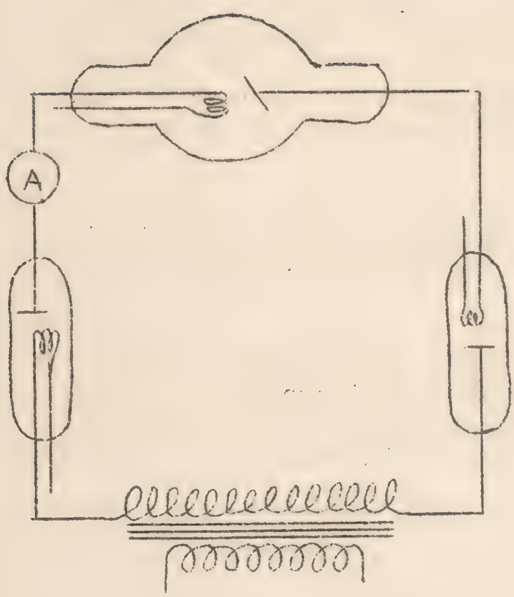
Valve tube x-ray machines are efficient. An x-ray tube operated by them does not vary its radiation output as compared with mechanical rectified equipment. The main advantage in the use of valve tubes is their silence of operation. Valve tube machines are equipped with the same controls as are the machines using other types of rectification and are operated in the same way. Although each valve tube has its own filament transformer, the adjustment of their filament circuits is not changed by the operator.



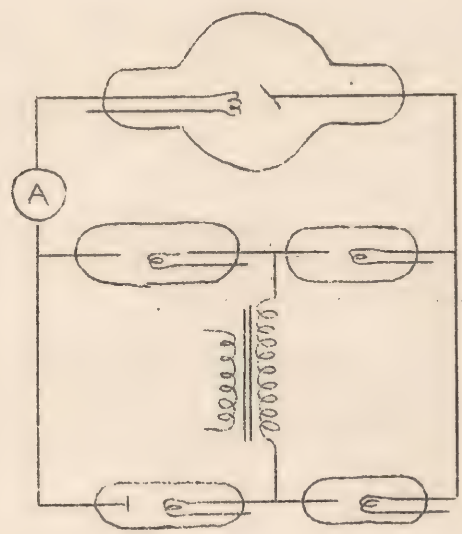
4. Rectification



A Valve Tube



Half Wave Rectifier



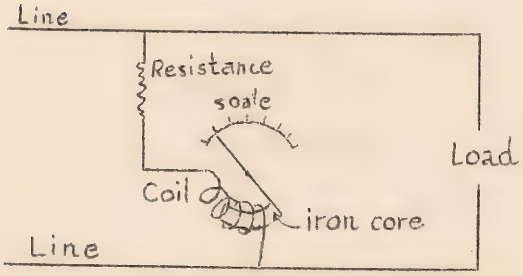
Full Wave Rectifier

Many instruments for measuring electrical units have been devised but the only ones of particular interest in connection with x-ray equipment are Ammeter, Milliammeter, Voltmeter, A ballistic meter, and the Sphere gap. The first four of these measuring devices are constructed on one of two principles. Those used for direct current are composed of a coil of wire with a pointer attached, mounted on a pivot so that it is free to rotate, and is located between the poles of a horseshoe magnet. When a current passes through the coil a magnetic field is built up which causes the coil to rotate. The amount of rotation, with the resulting movement of the pointer, depends upon the amount of current passing through the coil. The second principle, and that used for alternating current, is based on the fact that when a current is passing through a coil of wire a magnetic field is created which will tend to draw into it a soft iron core that is mounted so that it can move freely. A pointer attached to the core indicates the amount of movement.

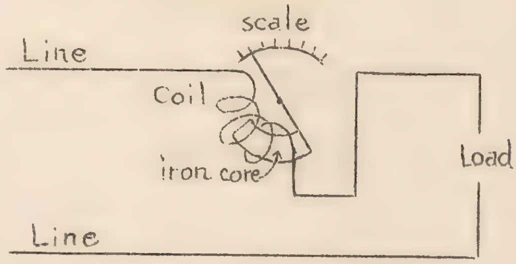
An ammeter of either the A.C. or D.C. type, is designed to measure the quantity of current (Amperes) flowing through any circuit. It functions in the same way as a water meter in that the entire flow must be through the meter, hence it must be inserted in one line of the circuit. In other words it is connected in series.

A milliammeter is essentially similar to the ammeter but standardized, or calibrated, to read milliamperes. It must be connected in series.

A voltmeter is designed to measure the pressure between the two lines of a circuit. It is connected 'across the lines'. It differs from the ammeter in that it contains a high internal resistance so that only a small portion of the current can flow through the meter.



A.C.VOLTMETER



A. C. AMMETER

A ballistic ammeter is designed to measure ampere values in terms of duration of time (milliamper seconds) and is only used for exposure of less than one second. The principle of operation of ballistic meters invokes inertia and momentum. In an ordinary milliammeter at least a full second is required for the pointer to reach a reading of 100 or more milliamperes. If

the desired exposure is to be only $\frac{1}{2}$ second, for example, then the exposure will have ended before the pointer had time to register the full amount of current. The ballistic meter will record the amount of energy received however short the exposure. It is calibrated to read milliampere seconds.

Sphere gaps are used to measure kilovolts peak. It is possible to construct a kilovolt meter, but the internal resistance required in such meters is so large they are not practical for use with radiographic equipment in the average laboratory. The sphere gap can be used to measure high voltages on the basis that in given atmospheric conditions and when using certain size spheres a given voltage will jump from sphere to sphere when they are just so far apart. If then, the two high tension lines of the x-ray machine are connected, one to each of the spheres and the spheres gradually brought closer and closer together a point will finally be reached when the amount of voltage in the circuit will jump the remaining gap. The distance of this jump indicates the voltage.

CALIBRATION

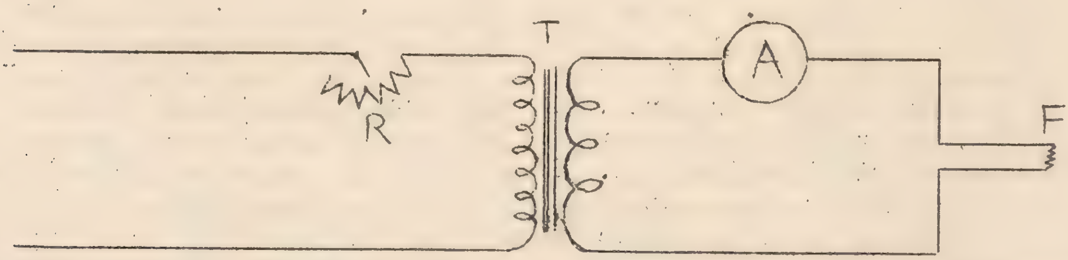
In modern shock-proof equipment calibration of equipment is confined to a minimum, in fact the only calibration necessary has to do with the milliampere selection. Every machine has a meter indicating the amount of current being applied to the filament of the x-ray tube. Readings are taken on this meter as the various milliampere values are obtained and are charted so that at any subsequent time any desired milliamper value can be obtained by simply setting the filament meter on the reading which the chart shows produced that milliamperage before.

In some of the older equipment it was necessary to calibrate the machine for high tension output using the sphere gaps mentioned above. In the new equipment, however, this calibration is done at the factory and all that must be done during the operation of the machine is to see to it that the line voltage compensator is set properly. The line compensator makes allowance for any voltage different from the voltage used at the factory for the original calibration. In this type of equipment the voltmeter which measures the output of the Autotransformer instead of being calibrated in volts (which it is actually measuring) is calibrated in terms of kilovolts. The kilovolts which will be produced when that voltage passes through the high tension transformer. It is called a pre-reading voltmeter, because one can read what the kilovolts output will be before the exposure is actually made.

For purposes of study the x-ray machine can be divided into three main circuits. These do not include the many auxillary circuits such as remote control switches and the like, but they are the main circuits upon which the production and control of x-rays is dependent. They are called the filament circuit, the primary circuit, and the secondary or high tension circuit.

The Filament Circuit is entirely separate from the other two and directly controls the quantity of x-rays produced. It consists of a rheostat or variable choke coil, a step-down transformer, an ammeter, and the filament of the x-ray tube.

The production of x-rays is dependent upon the liberation of electrons from the filament by means of heating it to a high temperature. This heating is accomplished by the electricity that passes through it. In order for an electrical current to have much power or heating power in such a filament it must be high amperage current. This is obtained by passing the line current supply, which is usually 110 volts, through a step-down transformer. Here the voltage is reduced to about 12 volts with a resulting increase in the amperage. Since the heat of the filament determines the number of electrons liberated, and the number of electrons determines the quantity of x-ray produced; it follows that some means of varying the filament current is necessary in order that varying quantities of x-rays may be produced as needed. This control is accomplished either by a rheostat or more usually by a variable choke coil. The ammeter indicates the amperage delivered to the filament, and by noting the ammeter reading at any given quantity production (milliamperage) it is easy to reestablish that same quantity of production at any time by simply adjusting the filament control so that the ammeter reading is the same as before.



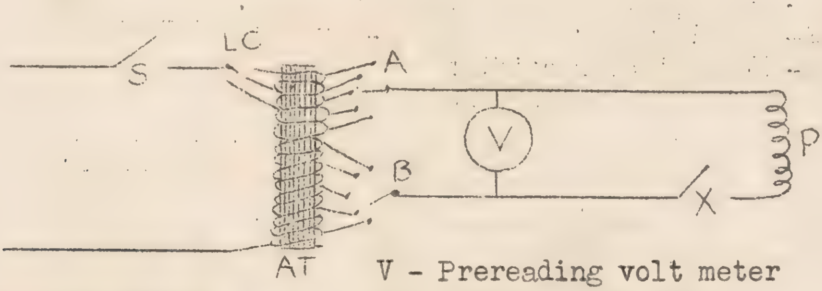
R - Rheostat or Variable Choke
A - Ammeter
T - Step-down Transformer
F - Filament, X-ray tube

FILAMENT CIRCUIT

The Primary Circuit is directly concerned with the selection of voltage to be delivered to the high tension circuit. This in turn determines the amount of kilovoltage delivered to

the tube and so controls the quality of the x-rays produced. In this circuit are included the Main line switch, the autotransformer, a pre-reading volt meter, and the x-ray switch.

The incoming line voltage is allowed to reach the autotransformer when the main line switch is closed. By means of the volt selector taps on the autotransformer the operator is able to select a voltage which, when delivered to the high tension transformer, will produce just the kilovoltage necessary to properly penetrate the part to be x-rayed. Since each part of the body requires a different amount of penetration the autotransformer plays an important part in the control of x-rays. The voltage leaving the autotransformer, passes to the x-ray transformer, or high tension transformer, when the x-ray switch is closed. A volt meter placed across the line between these two transformers pre-reads the voltage which will reach the x-ray transformer when the x-ray switch is closed. In the manufacture of most x-ray equipment tests are made at the factory on the kilovolt output of the x-ray transformer with various voltage input and then the pre-reading volt meter is calibrated in kilovolts. If such is the case, if that volt meter read 60 KV at a given setting, then when the x-ray switch was closed the autotransformer will deliver enough voltage to the x-ray transformer to produce 60 KV. The x-ray switch is usually operated by a remote control circuit and consists of a set of electro-magnetically controlled contact points.



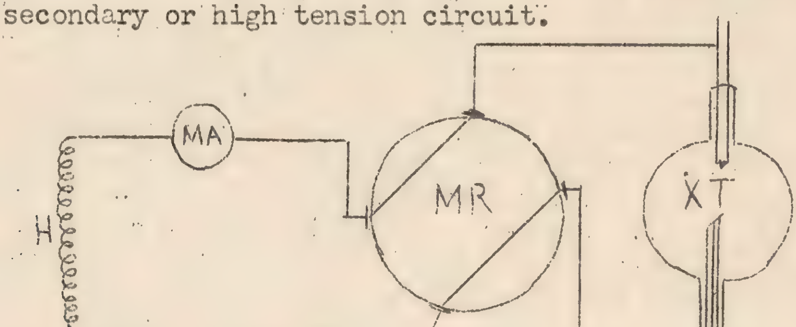
S - Main line switch
AT- Autotransformer
X - X-Ray Switch

V - Prereading volt meter
LC- Line compensator
A - Minor volt selector
B - Major volt selector
P - X-Ray transformer

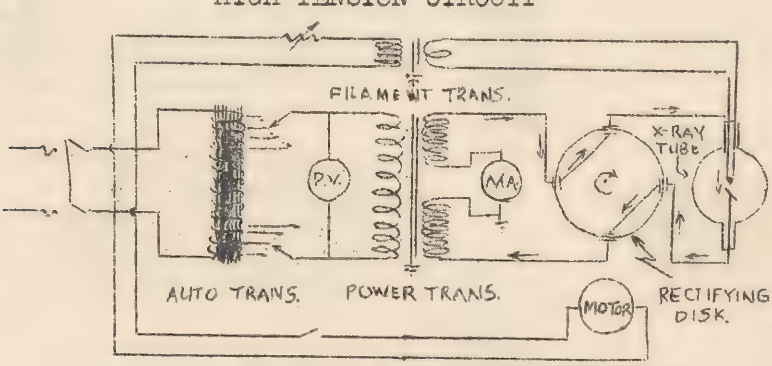
PRIMARY CIRCUIT

The <u>Secondary Circuit</u>, or <u>High Tension Circuit</u>, is that part of the wiring from the secondary coil of the high tension transformer to the x-ray tube. The equipment found in this circuit will depend upon the type of machine. The simplest form it may take, however, is a direct connection to the tube with one wire passing through a milliammeter. This would be a so-called self rectified machine. If the unit uses rectified current the rectification equipment will be included in this circuit.

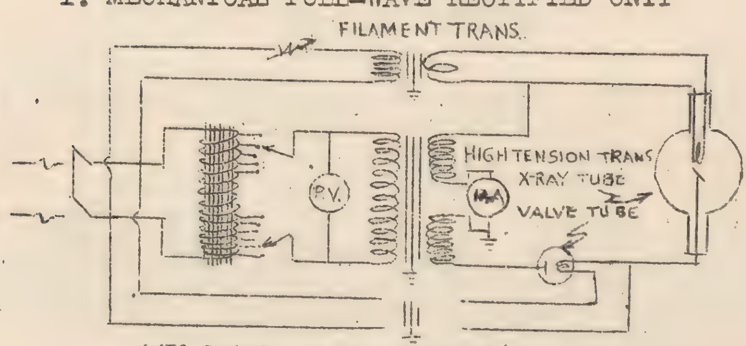
To produce x-rays electrons from the filament must be attracted across to the target with tremendous force. This attracting force is supplied by the positive charge of the high tension transformer. One side of the transformer is connected to one end of the tube and the other side to the opposite end of the tube. The current that flows through this circuit must pass through the x-ray tube, and the only way this current can pass through the tube is by means of the electrons from the filament. Since the bombardment of these electrons against the target produces x-ray it follows that the more current passing through the tube the greater the amount of x-rays produced. This current is measured by the Milliammeter which then becomes an indicator of the quantity of x-rays being produced. It must be remembered that no amount of voltage can pass through the vacuum x-ray tube unless electrons are made available by heating the filament and thatthe heat of the filament is controlled entirely by the filament circuit. It is the filament circuit then that controls the amount of flow of current in the secondary or high tension circuit.



H - S econdary of high tension trans.
MA- Milliammeter XT- X-ray tube
MR- Mechanical rectifier
HIGH TENSION CIRCUIT



1. MECHANICAL FULL-WAVE RECTIFIED UNIT



2. SINGLE-VALVE HALF-WAVE RECTIFIED UNIT

It has been shown that the production of x-rays is the result of three things, all of which must take place inside the x-ray tube. 1. Electrons must be set free from the filament; 2. These electrons must be set in rapid motion toward the target; and 3. They must be stopped suddenly on the target surface. This bombardment displaces some of the electrons of the atoms of the target itself and when these displaced electrons fall back into their orbits or are replaced by other electrons, the energy that was required to displace them is given out in the form of radiation or x-rays. If the energy contained by the bombarding electrons is only moderate because of only a moderate voltage applied to the tube then the energy of radiation will also be limited as evidenced by the longer wavelengths of rays produced. If, however, a high voltage is applied to the tube the bombarding electrons will possess a great deal of energy and will displace electrons from the inner orbits and when they are replaced a greater amount of energy will be given out as x-rays. Remember that greater and greater amounts of energy are required to displace electrons from the orbits nearer and nearer to the nucleus, and that this greater energy manifests itself in rays of shorter and shorter wavelengths.

This radiant energy is given out as bundles of energy which travel in waves similar to light waves but much shorter in length. The present known wave spectra comprises wavelengths ranging from .01 Angstrom Units up to about 30.000 meters. An Angstrom unit is one ten millionth of a centimeter. In this spectra there is a band of waves which comprise visible light with the short end about 4000 Angstrom units long comprising the color violet and the long end of the band about 8000 A. U. producing the color red. Inbetween are the other colors visible to the human eye. Above red in the scale of wavelengths is a band called infra-red rays and below the violet; extending down to about 120 A. U. is a band called ultra-violet. From 120 A. U. down to about .05 A. U. is the x-ray band. Since there are many combinations in which electrons in the tungsten atom can be displaced, a beam of x-rays is composed of x-rays with a minimum wave length which is proportional to the voltage applied to the target plus x-rays having a gradation of wavelengths from the shortest to the longest. The longest wave lengths generated by the target even though a high voltage is applied to the target are very easily absorbed by the first few layers of tissue. We call the whole beam of roentgen rays heterogeneous.

Roentgen rays may be classified in several different groups or types. First is primary radiation, which is that radiation emanating from the target of the x-ray tube and caused by the bombardment of that target by electrons from the heated filament. Next there is secondary radiation or that radiation emanating from any subdtance through which the primary rays may pass, and is thought to be caused by a bombardment

of the atoms of that substance by the primary x-rays. These secondary rays are produced in quantity directly proportional to the size anddensity of the object through which they are passing and as a result are a detrimental factor in the radiographing of large parts of the body. The secondary rays scatter in all directions from their points of origin and thus tend to fog the film. A third classification is termed characteristic radiation, and although it is relatively unimportant as far as the technician is concerned it is, nevertheless, interesting. It is the radiation produced when the speed of the bombarding electrons is sufficient to transfer enough energy to displace electrons from the K orbit of the target atom. The K orbit, it will be remembered, is the innermost orbit and the one which requires the greatest amount of energy for the release of its electrons. Every element has its own energy value required for displacement of electrons from the K orbit. For tungsten 69,000 volts (mean root square) is the requirement, while platinum requires 78,000 volts and gold 80,000. As the atomic weight increases (that is the atomic weight of different targets) a higher voltage must be applied to the electrons to displace an electron from the K orbit. Characteristic radiation spectra for various substances have been made and as a result of this investigation, Mosley found out that the elements can be arranged according to the roentgen-ray spectra in a sequence within which the displacement of the separate roentgen-ray lines occurs in perfect regularity from element to element so that every gap in the series is made manifest at once by too great a jump.

Of interest too, are the various properties of x-rays of which the following are the outstanding:

1. They are invisible and are transmitted through space in the form of waves similar to the propagation of light.

2. They travel in straight lines.

3. They can be reflected and refracted by crystals.

4. They are unlike beta and alpha particles in that they cannot be deflected by a magnetic field.

5. They travel with the speed of light, 186,000 miles per second.

6. Roentgen rays differ from light in wave lengths; roentgen-ray wave lengths vary from about 120 to .05 Angstrom units. (One Angstrom unit equals 10-8 or .000,000,01 centimeter).

7. They are produced by the impact of electrons on matter.

8. They ionize gasses through which they pass.

9. They will produce fluorescence and phosphorescence in some substances.

10. They produce chemical changes.

11. They produce biological changes which are probably due to chemical changes in the tissue.

Certain of the above mentioned properties are of special interest because of their every day use in the practice of radiography. For example the fact that x-rays ionize gasses. It is this principle that is utilized in the functioning of the Roentgen meter, an instrument that accurately measures the amount of radiation. More information about this meter will be discussed in a later chapter.

The property of fluorescence is made useof in at least two ways. Firstly, in the construction of a fluoroscopic screen a special chemical or mixture ofchemicals is spread on a cardboard and mounted in a frame. The part to be examined is placed between this screen and the x-ray tube and an image of the part is seen on the screen by means of the fluorescent glow. Fluorescence is that property of a substance to receive energy in one wavelength and give out that energy in another wavelength. In this case the chemicals receive x-rays that are invisible and converts those short wavelengths into long waves which are in the band of visible light. A second use to which this principle is put is in the use of intensifying screens. These are similar to the screen just mentioned and made to fit inside the film holder, one to the lid and the other to the base. A film lying between them will be exposed not only by the x-rays striking it but also by the fluorescent light produced when these x-rays strike the fluorescent chemicals. Hence the x-rays exposure is said to be intensified.

The fact that x-rays produce changes in certain chemicals is demonstrated in the production of an x-ray negative. As the x-rays pass through the varying densities of the part in varying quantities they expose the film in varying degrees. Directly under the dense areas of the part exposed only a few rays strike the film and the resulting chemical change is minimal, however, around the border of the film where the full x-ray beam strikes the film directly the chemical change is intense and as a result the developed film shows corresponding light and dark areas. This chemical change cannot be seen by any means before development but is demonstrated by the reaction of the exposed chemicals to certain chemical reagents in a solution which is called 'developer'. The nature of this change is unknown.

The biological changes they produce in the tissues is made use of in the treatment of certain diseases and will be discussed fully in a later chapter dealing with x-ray therapy.

It has been mentioned that one of the physical properties of Roentgen rays is that it has certain effects on living cells. This fact is the basis for the use of these rays in the treatment of many diseases and as well is the reason for such extreme care in the use of this very useful agent. Many brilliant and skillful men have been disfigured and many have died because of ignorance of the harmful physiological effects of radiation, particularly in the early years following its discovery.

To simplify the subject somewhat we may consider the fundamental effect of Roentgen Rays on living tissues to be destruction of the cells which absorb the energy of the rays. Many authorities feel that this destruction of cells is accomplished by the ionization of the cell with resulting chemical changes incompatible with continued metabolism. Whatever the mechanism is, however, we know that cells are destroyed when Roentgen Rays are absorbed and that destruction of cells is the only thing that we can be sure does occur.

All cells of the body are not affected equally by Roentgen Rays. Some are destroyed by relatively very small doses whereas others require tremendous amounts of radiation before any effect can be noted. The question of susceptibility to radiation seems to depend to a great extent upon the relative age and development of the cells involved. The more rapidly developing cells which have a rather short span of viability are more easily effected and the older "adult type" cells are less easily destroyed. It is logical to find, then, that the order of susceptibility is roughly: blood cells (particularly the polymorphonuclear cells); skin and elements which embryologically are derived from ectoderm such as sperm-cells and ova, gland structures, hair, finger and toe nails, etc; normal bone; muscle; and normal nerve cells.

In Roentgenography we are particularly interested, as far as the operators are concerned, with the possibilities of destroying large numbers of blood cells (particularly the polymorphonuclear leucocytes) and the genetic cells, by repeated, small doses of x-ray. It is felt that as little as one or two roentgens a day is above the limits of safety for one who consistently works with radiation. Protection against even this small amount of energy is accomplished by observing certain basic rules of distance maintained between the operator and the primary beam of radiation, and the use of lead protection in the form of gloves and aprons for roentgenoscopy and leaded shields and control stands for roentgenography. It must be remembered that the technician should never allow any of his body in the primary beam as might be thought necessary at the moment to hold a part for roentgenography or to assist the orthopedic surgeon in reducing a fracture under roentgenoscopy, as such a practice will almost surely result in a burn. The x-ray burn is the result of the destruction of the cells of the skin as just described and is extremely serious because of the difficulty with which it heals. Because of this terrible chronicity and the further danger of the tendency of constant irritation and infection of the lesion to predispose to malignant degeneration it has frequently been necessary to amputate the involved extremity.

Naturally, this same danger of destruction of the cells of the skin resulting in an x-ray burn applies to the patient. In every aspect of Radiology the potential danger of burning the patient is constantly present. In therapy the radiologist must be alert to the danger and know accurately how much radiation the patient can tolerate and the technician must be meticulously careful that the factors and dosage are exactly those the radiologist ordered. In roentgenoscopy there are relatively limited ranges of factors used and the quantity and quality of the radiation received by the patient at these factors has been accurately measured so that the radiologist can stay well within safe limitations in establishing his diagnosis. In roentgenography charts have been prepared indicating the safe limits of exposure (as measured in milliampere seconds) for the kilovoltage range ordinarily used in roentgenography (i. e. 35 to 90 K.V.P.). As the inverse square law, common sense and the chart all indicate, it is vitally important to know the focal skin distance and to look up the skin tolerance in every case in which three or more exposures of the same area are to be made. This is especially true if the exposures are to be more than 200 M.A.S. apiece as might be the case in lateral lumbar spines or other thick parts.

TABLE OF EXPOSURE VALUES WITHIN SAFE LIMITS

HEAD

Focal-skin Distance	No Filter	1/2 mm. Al Filter	1 mm. Al Filter
8"	157	191	255
9"	194	264	324
10"	238	300	400
11"	292	363	484
12"	346	431	575
13"	405	507	675
14"	470	589	784
15"	540	675	900
16"	616	769	1025
17"	691	864	1152
18"	777	971	1295
19"	866	1083	1444
20"	964	1200	1600
21"	1059	1322	1762
22"	1159	1451	1935
23"	1269	1583	2115
24"	1382	1728	2304
25"	1502	1873	2502

TABLE OF EXPOSURE VALUES WITHIN SAFE LIMITS (Continued)

ALL PARTS EXCEPT HEAD

Focal-skin Distance	No Filter	1/2 mm. Al Filter	1 mm. Al Filter
8"	202	255	341
9"	259	324	432
10"	317	400	533
11"	389	484	645
12"	461	575	768
13"	540	675	900
14"	626	784	1044
15"	720	900	1200
16"	821	1025	1368
17"	922	1152	1540
18"	1037	1295	1728
19"	1152	1444	1920
20"	1282	1600	2136
21"	1411	1762	2352
22"	1548	1935	2580
23"	1692	2115	2820
24"	1843	2304	3072
25"	2002	2502	3336

After any part has received the full exposure limits in m.a.s. a minimum of twenty-one days should elapse before further exposure is given.

To summarize - We may consider the fundamental physiological effect of Roentgen Rays to be destruction of cells. Because of the variation in the sensitivity of different types of cells many types of reactions to radiation can be demonstrated. Some of these reactions are definitely undesirable as in the case of anemias, burns, and cancers produced by unwise radiation. While some of the reactions, when controlled as is explained under the discussion of therapy, are helpful in treating certain diseases. In either case it is of utmost importance that we know and understand the dangers in order to obtain the many advantages without eliciting the tragedy of its treachery.

X-Rays are produced when electrons, traveling at high speed collide with matter in any form. It is a known physical fact that hot bodies, particularly in high vacua, liberate electrons and the number of electrons thus emitted is dependent upon the temperature of the radiating source. In summing up the factors necessary in the production of x-rays, then, it can be said that electrons must be liberated from the cathode, directed toward a given spot on the target at high speed, and then suddenly stopped by that target. The source of these electrons is a coil of tungsten wire which is mounted in a focusing cup which is supported by a stem which is fused into the cathode end of the glass bulb. The size and shape of the focusing cup and filament deciding the size of the focal spot on the target. The electrons are liberated from this coil only upon heating. This is accomplished by a current of 4 to 5 amperes and about 12 volts, obtained from the step-down transformer, called the filament transformer. When incandescence takes place, electrons are given off from the lighted filament and provide a bridge, as it were between electrodes. The amount of electrons given off depends upon the degree of heating of the filament - the hotter the filament the more electrons - and the amount of electrons represents the milliamperage factor. It is increased or decreased by the use of the filament rheostat on the control stand.

After the liberation of electrons it is then possible, by the application of high potential across the terminals of the x-ray tube, to drive a "pencil" of electrons from the cathode to the target with the resultant production of a beam of x-rays. This potential is accomplished by attaching the negative lead from the rectifier to one of the filament leads and the other or positive wire to the anode. The negative electrons, for electrons are negatively charged particles, are repelled by this negative current in the cathode and are attracted by the positive anode or target. The violence with which these electrons are repelled by the cathode and attracted by the anode depends upon the amount of tube voltage allowed to reach the tube. This constitutes the second factor in the production of x-rays, which we called penetration or, more strictly, kilovoltage (K.V.). These facts may be simply stated as: The higher the tube voltage the greater the speed of the electron stream. The greater the speed of the electrons the greater the impact on the target. The greater the impact on the target the shorter the x-ray wave length. The shorter the x-ray wave length the more penetrating the x-ray. The converse of the above is also true. Regulation of the K.V. is achieved by means of the auto transformer located in the primary circuit. This transformer is a step-down transformer in effect and serves as a volt selector. The voltage that is selected passes to the high tension transformer where it is stepped up according to the ratio of that particular transformer - usually 1:500 or 1:1000, the former for 220 volt input and the latter for 110 volt input equipment.

From the high tension transformer the alternating current passes through the rectifying system on its way to the tube.

Not only is it essential to be able to accurately control the production of x-rays but it is important to know how to control the rays after their production. Any of the body tissues may be damaged by over exposure to the x-rays - the skin, the blood, and some of the internal organs being the most sensitive. In the laboratory protection must be given the operator as well as the patient. In fact the consideration given to the protection of the operator is the most pertinent for at least two reasons; first, the patient ordinarily will have only a few x-rays taken during any one illness and in the usual radiographic examination,the amount of radiation received by the patient is but a small fraction of the dose which would produce bodily harm. Second, the operator is exposed continually to small doses of scattered rays, and at times to the primary rays. Unless such exposure is kept to a minimum, the cumulative effect is apt to cause damage to the body. In view of these facts, then, it is obvious that to protect the patient the rule should be that: before any x-ray exposures are made on any patient, the patient should be questioned as to any recent exposures, and if repeated exposures are to be given any one area, caution should be exercised to avoid excess.

The operator, to protect his own health, must constantly guard carelessness in allowing any exposure of himself. Not only the operator but any person in the x-ray room during an exposure, except the patient of course, should place themselves not closer than 6 feet from the central ray and preferably behind a lead screen or wall. The hands should not be behind the fluoroscopic screen or used to immobilize parts for radiographic work without the use of lead gloves. No fluoroscopic screen should be used that is not protected by a lead glass and when regular fluoroscopy is done the operators should wear lead aprons.

In modern equipment the manufacturers have done everything possible to eliminate stray radiation. This has been done in many ways but perhaps the outstanding ones are the leaded cases in which the tube is inclosed, the lead diaphragms between the tube and the fluoroscopic screen which limits the exposure area to the size of the screen which itself is a barrier to x-ray because of the lead glass covering. Some tubes are already equipped with from $\frac{1}{2}$ to 1 mm of aluminum covering the port - if the tube is not already so equipped this filter should be added before radiological work is done with it.

To determine whether he is receiving an excessive amount of x-radiation, the operator may attach a paper clip (by means of adhesive tape so that the clip cannot move about on the film from day to day) to a dental film packet and wear it on the front of the chest, with the tube side away from the body for a period of fifteen consecutive working days. If, upon development, the film shows an image of the clip, the protective measures should be increased. X-ray operators should be given blood tests at frequent intervals to guard against any damage to the blood from x-ray exposure. They should spend as much time as possible in the open air and especially in the sunshine.

The use of shockproof equipment is now so prevalent that electrical dangers have been almost eliminated. However, the safety provided by this type equipment is of itself a danger because it is likely to relieve too completely the mind of the operator. After handling trustworthy shockproof equipment, there is considerable likelihood that the younger technicians may fail to recognize the electrical hazards which exist as far as the operation of non-shockproof equipment is concerned. Moreover, everyone should realize that regardless of self-contained tube heads, or with the use of shockproof cables, one is still handling currents of exceptionally high voltage which under certain conditions might resist the protective provisions. Therefore, even with modern shockproof equipment, the possibilities of electrical hazards should be respected.

Death, as a result of electrical shocks, may result from one of several physiological effects but it is estimated that approximately 90% of maleffects incident to electrical shock are those concerned with the heart. Regardless of the unfavorable possibilities, every effort should be made to restore the victim from electrical shock. Artificial respiration should be instituted as soon as possible and continued for from 2 to 4 hours - awaiting the arrival of the doctor.

XVI. X-RAY APPARATUS AND ACCESSORIES

In the field of x-ray, just as in the field of automobiles, there are numerous makes, models and styles. To enumerate and describe all of these would not only be a hugh task but one of little value to the technician. It is a great deal more important that the technician understand the principles of operation of x-ray equipment in general for this knowledge will enable him to quickly accustom himself to the peculiarities of a particular piece of equipment so that he can handle it efficiently. It is possible, and valuable, however, to mention the various types of equipment and accessories which are commonly used.

A. Tables - The tables upon which the patient is positioned fall into five main classes.

1. Tilting - these can be turned from the horizontal position to the vertical position by means of a crank and gear arrangement included in the table, or in some cases by a motor driven gear system. The movement is made with the patient on the table and is particularly valuable in cases where fluoroscopy is done in both positions.

2. Stationary - these are permanently fixed in the horizontal position and cannot be tilted. They are not so desirable and hence not too widely used.

3. "G. U." - This is a table especially designed for use in examinations of the genito-urinary system. The table, instead of being full length, is only long enough to accommodate the torso and the lower end of the table is equipped with leg supports which hold the knees apart and flexed, giving ready access to the genitalia.

4. Orthopedic - these tables vary in design but are all especially adapted for orthopedic work. They have special frames in which the extremities can be immobilized and even held in traction while manipulation of fracture fragments is done.

5. "Army Field Unit" - this is a metal table frame designed for the Army. It is sectional and can be packed in two field chests. It is complete with movable tube stand attached. An arm with a fluoroscopic screen can be attached making possible fluoroscopy and foreign body localization. (See TM 8-275 "Military Roentgenology" Page 40,41)

2. X-Ray Apparatus and Accessories

B. Machines - Types

1. Radiographic units - Employ exposure of x-ray film as well as fluoroscopy.

   a. Stationary - too large to be moved without dismantling; vary in capacity from 100 MA to 500 MA. May be self rectified, half wave rectified, or full wave.

   b. Mobile - small enough to be built on a wheeled base so the unit may be pushed from room to room. The usual capacity is 25 to 50 MA.

   c. Portable -a still more compact unit than the mobile. Capacity from 10 to never more than 30 MA. Can be quickly dissembled and packed in carrying cases for movement from place to place. Example: Army Field Unit. TM 8-275 Page 26.

2. Therapeutic - Designed specifically for x-ray therapy and not film exposure. Have high voltage ranges but with low MA values.

   a. Stationary - large units permanently mounted and with capacities varying from 200 KV to as much as 1000 KV in a few cases. Designed to treat 'Deep Therapy' cases as well as skin or 'Superficial Therapy'.

   b. Mobile - Smaller therapy units built on mobile bases and because of the necessary compactness to permit mobility have lower KV output, usually from 100 KV to 180 KV.

3. Fluoroscopic - These units are designed for fluoroscopic use only and usually are limited to vertical position.

C. Accessories - the various devices used with the equipment mentioned above.

1. Timers - instruments for governing the length of the x-ray exposures. The simplest form is the

   a. Spring type - where the pointer is turned to the point on the dial which represents the length of exposure desired. The turning of the pointer tightens a spring which then pulls the pointer back to 0 when the 'button' is pushed to start the exposure.

b. Motor Driven - this timing device is operated by a small synchronous motor and is more accurate than the spring type - also much more costly.

c. Impulse Type - a motor driven timer of special design permitting accurate exposures of short duration, usually from less than one second down to 1/120 of a second or one impulse (when operated on 60 cycle current). In this and the regular motor driven timer the circuit is made and broken during the alternation change so that no current is flowing at the time and hence there is no sparking to burn the contact points.

2. Filters - in general no radiographic work is done without at least 1 mm (millimeter) of aluminum being added to the inherent filtration present in the tube. The purpose of these metal filters is to absorb the very long wavelengths of x-ray, the so-called 'soft' rays. These rays have the greatest effect upon the skin and so should be eliminated to avoid skin damage from long exposures. They are placed in the slot provided at the mouth of the tube so that all rays leaving the tube must pass through the filter. In therapy radiation much more filtration is used, the actual amount being determined by the voltage used, the tube-skin distance, and the depth of penetration desired etc. In this work other metals, like copper, thorium and others, are used in addition to aluminum. Each different metal has its own filtering characteristics which determine when it is to be used.

3. Cones - the greater the area exposed to x-ray radiation the greater the amount of secondary radiation produced. To minimize this secondary radiation heavy walled metal cones are used to confine the exposure solely to the area under study. The cones are suspended, by the small end, from the port of the tube - the size of the area under study determining the size of the cone to be used.

Base

4. Cylinders - used for the same purpose as cones but designed as cylinders so that an outer layer can be slid downward to extend the length to suit the need.

5. Ports - where cones or cylinders are not available a port may be substituted. It consists of a sheet of lead cut to fit into the slots at the mouth of the tube and having an opening in its exact center through which the x-rays may pass. This acts as diaphragm and in reality simply cuts down the size of the tube port. This serves to limit the area of radiation on the part being studied. The opening in the port can be of any suitable shape - a round hole for sinus work and a long narrow slit for spine work, for example.

6. Immobilization devices - used to insure against movement of the part during the exposure.

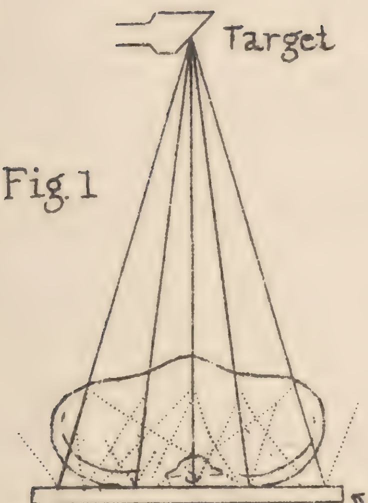
   a. Bands - attach to the table on one side, pass over the part and attach to a roller on the near side, a rachet holds the roller from unwinding so that the band may be drawn tightly and held taught.

   b. Sandbags - can be laid across the part or leaned against it to hold it still. Small sandbags or bags of shot can be placed in pockets, one at either end of a band long enough to cross the patient and hang over each side of the table.

7. Potter Bucky Diaphragm - a device to decrease the amount of secondary radiation reaching the film. It consists of a grid made up of thin strips of lead separated by thin strip of wood which are placed on edge and held firmly together. This grid is fastened in place above a metal tray in which the film is placed for exposure - that is, the grid lies between the patient (just under the table top) and the film holder. The secondary rays which are traveling in all directions toward the film are stopped by the lead strips unless those rays are parallel with the primary beam, in which case they pass through the wood strips between the lead strips and expose the film. In the latter case the secondary rays do no harm or practically none. The grid is attached to a mechanism which causes it to move across the film during the entire length of the exposure. It moves slowly across

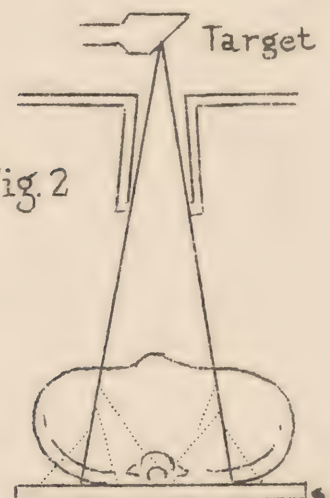
when the exposure is long and very rapidly when the exposure is short so that in every case the grid makes its full travel from one side to the other during each exposure whether short or long. By moving during the exposure the lead strips fail to cast a shadow on the film but simply remove an entire layer of x-rays as the strips move across the film.

Fig.1



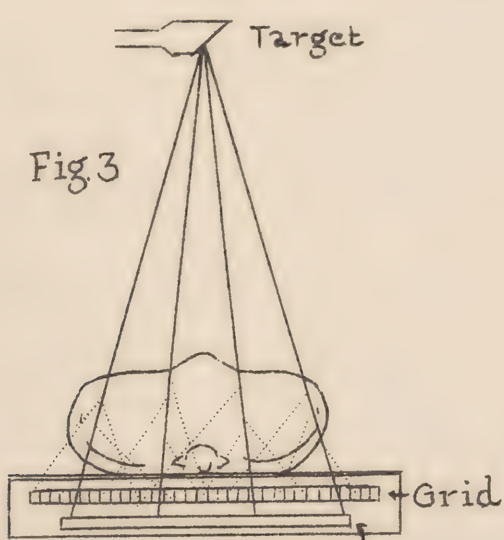
CASSETTE AND FILM
NO CONE

Fig.2



CASSETTE AND FILM
WITH CONE

Fig.3



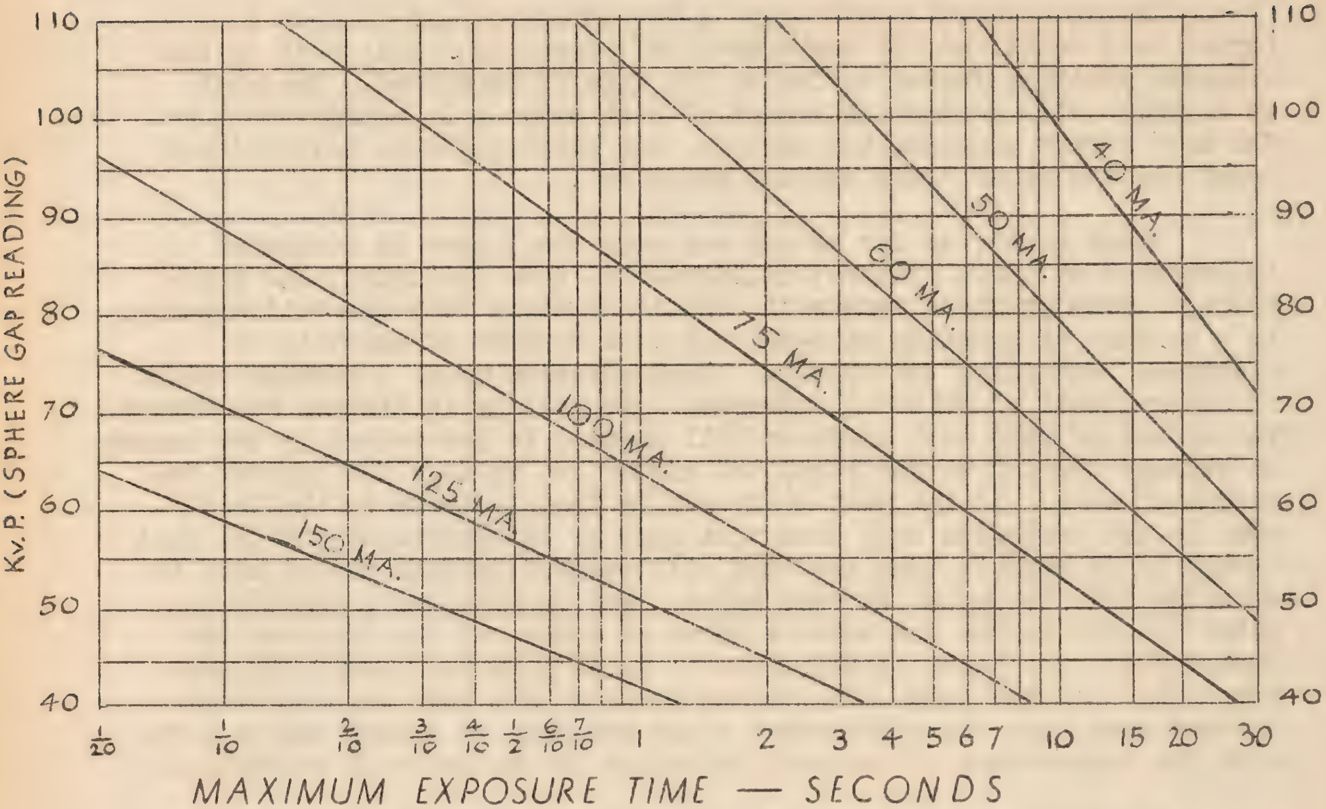
CASSETTE AND FILM
FLAT BUCKY DIAPHRAGM

XVII. TUBE RATING CHARTS

In the production of x-rays a tremendous amount of heat is formed as a result of the bombardment of electrons. This heat is the exposure limiting factor as far as the tube is concerned. Too great an exposure will produce an amount of heat which will damage the tube. The heat formed presents two aspects, one which might be called 'spot heat' and the other 'heat storage capacity'.

'Spot heat', as far as any one size focal spot is concerned is effected by three factors; milliamperes, time (seconds), and kilovolts. From previous lessons it should be clear that the milliamperage is a measure of quantity of x-ray and so a measure of quantity of electrons bombarding the target. Each electron bears a certain amount of energy, most of which is converted into heat as it strikes the target. The amount of heat each electron will produce is determined by the amount of voltage applied to the tube, the higher the voltage the greater the amount of heat. If the heat delivered by the electrons to the focal spot is not conducted away from that spot by the surrounding metal fast enough it is obvious that the spot will eventually gain enough heat to actually melt the metal at that point. For example, if a magnifying glass is held in the sun above a piece of paper and the distance adjusted until the light is focused on a small spot the paper will soon catch fire at that spot. The reason is that more heat was delivered to that spot than the surrounding paper was able to absorb and as a result the temperature of the spot increased to the point of combustion.

The milliamperes represent the number of electrons striking the target, the voltage represents the quantity of heat each electron bears, and, of course, the time is the number of seconds these other two factors are allowed to act. Then for any given size spot it can be said that the greater the M.A. and K.V. the shorter the exposure time allowable. The size of spot, two, determines the capacity of the tube since the larger the spot the greater the area over which the heat is spread and the greater the area of conduction into the rest of the target structure. Chart A deals particularly with 'spot heat' and from it one is able to find the maximum exposure allowable with any particular set of factors. This type of chart is furnished by the manufacturer of the tube and pertains to that one make and model of tube only. The usual method of using this chart is to decide on the factors you wish to use, then, by use of the chart, find if they are within the safe exposure limits.



Fluoroscopic and Therapeutic Ratings on Full-wave Rectified Equipment.

CHART A

The second capacity factor, heat storage capacity is governed by two factors, the mass of the anode structure and the type of cooling mechanism. The larger the anode structure the more heat it can receive before its temperature is raised to a danger point. Likewise, the more efficient the cooling mechanism the faster heat will leak out and, as a result, the faster heat may be put in; in other words, the greater the effective capacity. The chart covering this aspect of tube rating is called the 'cooling chart'. The heat storage capacity is stated in heat units. The number of heat units of a given exposure is determined by multiplying the milliamperes by the kilovolts and that result by the number of seconds of the exposure, or MAS x KV.

If a given tube has a rating for heat storage of 75,000 heat units and a series of exposures have been made in rapid succession totaling 75,000 heat units, then the tube contains its maximum amount of heat. If still another exposure must be made there must first be a period of rest of sufficient length to permit the cooling mechanism to get rid of at least the number of heat units which the next exposure will contain. The length of such rest periods can be determined from the 'cooling chart'. To do this find the curve line corresponding

to the number of heat units the target contains and follow it downward until it crosses the heat unit line (running across the chart) to which the target heat units must be reduced to make room for the new exposure, and directly below, at the bottom of the chart, read the number of minutes of rest required. Chart B is a sample of such a chart. Like any other tube rating chart this chart applies to a specific make and model of tube.

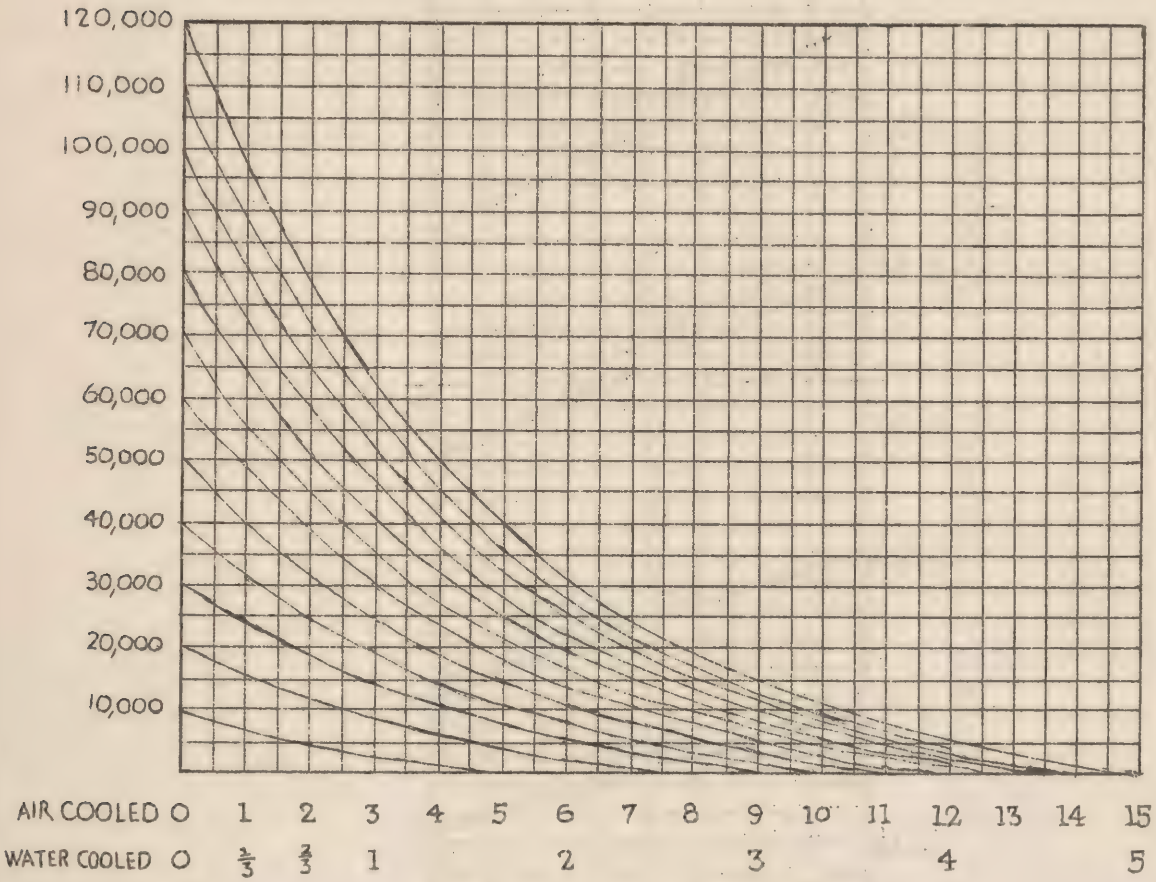


CHART B

Chart C is a sample 'Filament Increment' chart by means of which one can find the filament ammeter setting which produce any given milliamperage. This chart may be absolutely necessary at times as will be illustrated in the following example. If a tube you are using can tolerate 100 milliamperes at 70 Kilovolts for only 2/10 of a second then an Increment chart is the only means of determining where to set the filament control to produce enough heat in the filament to deliver 100 milliamperes of current. The ammeter setting cannot be decided upon by testing since the milliammeter will not have nearly enough time to record 100 milliamperes in the allowable time of 2/10 seconds. We can, however, make a test at a lower value where the time permits an accurate reading of the meter. With this as a

standard and by consulting the chart a value is found which is the amount of filament amperes to be added to what produced this lower value and the new ampere reading then will result in the production of the desired high milliamperage.

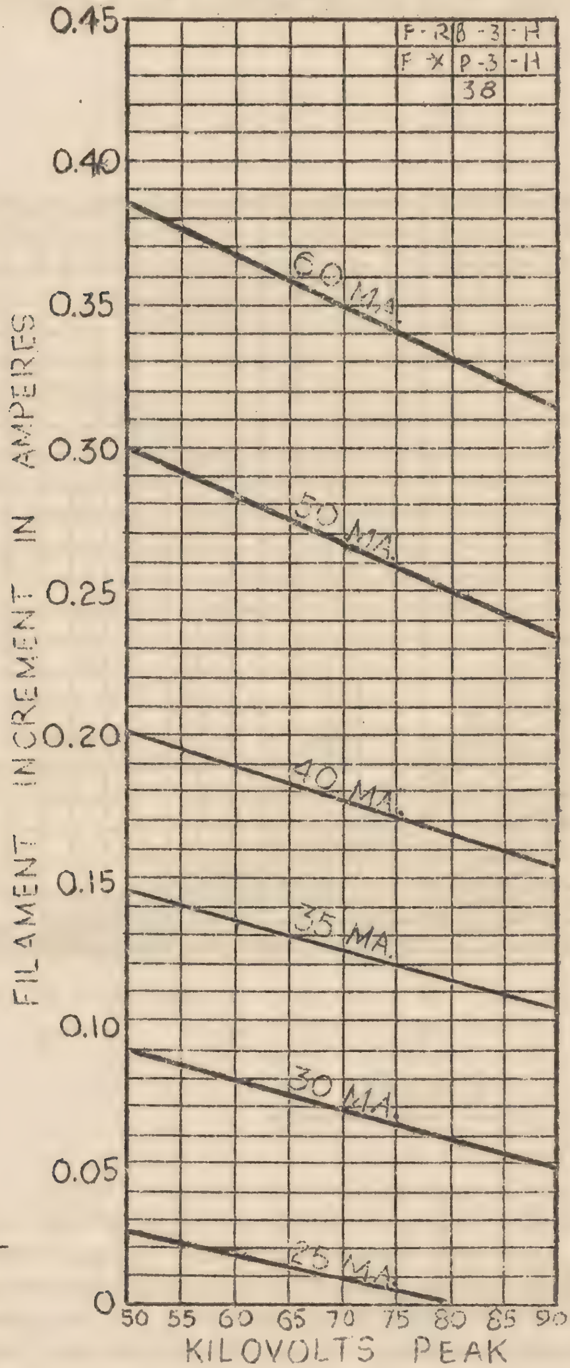


CHART C

Example: Assume the base value is 4.27 amperes, which is the filament current required to produce 25 ma. at 80 kv. p. If it is desired to operate at 60 ma., 65 kv. p. we follow along the 60 ma. curve to the point where it intersects the 65 kv. p. vertical line. The filament increment in amperes as indicated by the scale on the left hand side of the chart, is 0.36 amperes, which is the amount by which the base value should be increased to obtain 60 ma. at 65 kv.p.

In the early days of Roentgenography the hazards of the procedure were by no means limited to the x-ray machine with its uncovered wires and unshielded tube, but also existed in the dark room. X-ray negatives were glass plates which were coated with a sensitive emulsion composed of gelatin containing a silver compound. These glass plates were easily broken in various of the processing steps and caused many injuries to workers.

In time a remedy was found for this hazard, in the form of a thin film of nitro-cellulose. This nitro-cellulose base was coated on both sides with gelatin emulsion. This new base was somewhat similar to celluloid but more transparent and more pliable. There was just one thing wrong with it - that is from a safety standpoint - it was highly inflammable. Many severe fires in hospitals and other institutions resulted from a carelessly handled cigarette or match in the x-ray filing room or in the dark room. Insurance rates were increased on any building which contained this type of x-ray film. The film, when burned, gave off an obnoxious and poisonous gas. These facts all but offset its good points - easy to handle, non-breakable, and easy to store, etc. Research solved the problem by producing transparent, blue-tinted, cellulose acetate base which possessed all the good points of the nitro-cellulose base plus the quality of being slow burning. The Fire Underwriters Laboratories have judged the hazards of this new safety film to be very small, and when in storage to be somewhat less than would be presented by an equal quantity of common newsprint paper.

Before film storage and film handling and processing can be discussed it is necessary to mention a few more details of its composition. This cellulose acetate base is coated on both sides with a gelatinous emulsion containing certain silver salts, namely, silver bromide, silver chloride, and silver iodide. This emulsion is about .001 of an inch thick.

From the delicate nature of both gelatin and silver salt it is obvious that the emulsion is very sensitive to treatment of any kind; so when x-rays strike it, a change takes place in its physical structure. Although this change is of such a character that it cannot be measured by any known physical method, the exposed film may be treated with a chemical solution - called developer - which will effect a definite reaction that causes the deposit of tiny granules of black, metallic silver. It is this silver, suspended in the gelatin on both sides of the base, which constitutes the image.

While an image may be formed by light, gamma rays, and other forms of radiation, as well as x-rays, the properties of the latter are of a distinct character, and for this reason the sensitive emulsion must be radically different from those used in photography. There are two types of film now in use (1) "screen" film, which is especially sensitive to the fluorescent light of intensifying screens and not so sensitive to the direct action of x-rays; (2) "direct exposure" or "non-screen" film, which is highly sensitive to the action of x-rays but cannot be used with screens. The former, when used with intensifying screens, is always faster than the latter for any part and exhibits less sharpness of detail. In other words screen film is

faster but less sharp; whereas non-screen film is slower but more sharp. This difference in detail is not due to the difference in length of exposure but simply and wholly to the fluorescent light of the intensifying screens. This light is emitted from each small particle of calcium tungstate on the screen and spreads in all directions. This results in a certain amount of overlapping of light from adjoining particles and hence a slight fuzziness of detail. On the other hand, in the use of non-screen film, exposure of the film is accomplished by the X-Rays alone.

There is no set rule as to which of these films is to be used for any given part, however, as a general rule it is well to use "screen" film on all heavy parts, such as the trunk and skull, and "non-screen" films on the smaller parts, such as the extremities. When other than normal conditions prevail the final selection of the type of film for a certain part must be governed by the nature of these conditions. For example, non-screen films would not be the choice in taking a radiograph of any extremity if it is in a plaster cast and the picture is to determine the amount of callus because the added detail would also emphasize the casting material fibres, etc.,and make differentiation difficult.

Since X-Ray film is particularly sensitive to the action of X-Rays, and is also highly sensitive to gamma radiation, it should always be stored at the greatest practical distance from the source of such energy and protected by lead. Since gamma radiation is particularly penetrating, special precautions must be exercised whenever radium is kept in the laboratory. Film must be stored in a cool, dry place and bought in such quantities that the supply is renewed frequently owing to the fact that both moisture and heat, as well as long time storage produce deleterious effects. Under no circumstances should film be left in a drug room or any location where there is leakage of illuminating or other types of gasses, or where there is possibility of contact with formalin vapors, hydrogen sulphide, ammonia, or hydrogen peroxide. In other words the dangers of storage can be summed up in five points. Heat, moisture, X-Rays, gamma rays, and chemical fumes. One precaution has not been mentioned because it is so obviously common knowledge - do not open film except in a dark room.

In handling films great care must be exercised to avoid physical damage to the emulsion, such as pressure, creasing,buckling, etc. as each of these produces imperfections in the finished film. If large films are handled they should always be grasped by the corners and allowed to hang freely. Dental films are held with opposite edges between the fingers and in this way finger marks are precluded. Another important caution to remember is to avoid drawing film rapidly from cartons, exposure holders or cassettes, or handling it in any manner that would cause friction. Such care will help materially to eliminate the occurrence of objectionable circular or tree-like markings in the radiograph which are due to the discharge of static electricity, or result from physical strains.

Identification, X-Ray records and filing of X-Rays are important essentials to be considered. Without some means of incorporating identification data on the film it would be virtually impossible to keep track of any particular patient's films. Since from a medicolegal standpoint it is necessary to keep films on hand for a number of years they must be adequately marked and just as adequately filed, and recorded. The identification data may be incorporated in the film at the time of exposure by means of lead letters. This must include, at least, the date and the patient's X-Ray number as well as an R or L placed in such a way as to indicate clearly the patient's right or left side. Other data which may be included consist of letters to indicate the direction of the central ray as AP, PA, etc., an arrow pointing in the direction of the tube shift (in the case of stereoscopic films), as well as the patient's name and the name and address of the laboratory taking the X-Rays. The Eastman Kodak Company has a device which photographically prints on an unexposed corner of the film any information desired by merely typing the information on a slip of paper and exposing the film with the paper over it to a special light.

Filing methods vary in different laboratories but the two most common methods are as follows: Films filed according to number. This method requires an adequate system of cross files to go from name to number and from number to name. Another method, and one probably inferior to the one just mentioned, is filing alphabetically. In this method if the volume is large there will be difficulty in finding any given name quickly.

In considering films and their usage, mention must also be made of film accessories, the most important of which is the cassette. Cassettes are light-proof holders in which the films are placed while in the dark room where they are closed and sealed by means of clamps, after which they may be brought out into the X-Ray room and subsequently exposed by X-Ray. Of these, there are two types. One type, the type that is most commonly called a cassette, is a metal frame with a metal hinged back and an aluminum or bakelite face. This type of holder contains a pair of intensifying screens, one fastened to the inside of the back and the other to the inside of the face, so that the film lies between the two screens when closed.

When an X-Ray beam strikes an X-Ray film, less than 1% of the radiant energy is absorbed by the emulsion, and, as a result, more than 99% fails to perform any useful radiographic work. Since the absorption of the rays by the emulsion primarily governs the formation of the latent image, it is obvious that in many situations a means of more fully utilizing their energy, without complicating the technical procedure, is highly desirable. The function of the intensifying screens inside the cassette is to increase the effect of the x-radiation on the sensitized emulsion and thus reduce exposure.

The principle involved is simply that certain chemicals have the ability to absorb X-Rays and instantaneously emit blue-violet light - a property called fluorescence. X-Ray intensifying screens

embody such a compound, a white crystalline salt, calcium tungstate, being the one most commonly employed, because of its effectiveness as a fluorescent agent and its general advantages in manufacture and in use. It is finely powdered, mixed with a suitable binder, and coated in a thin, smooth layer on a special cardboard support. It is apparent then that with the use of screens we not only utilize the 1% of energy normally absorbed by the film, but also use another and larger percent in producing the fluorescent light which also exposes the film. In the use of these screens two important features must be constantly kept in mind. One, that a check must be made occasionally to insure that the contact of the screens with the film is adequate, for if it is not, the image on the film in the area of the poor contact will be fuzzy. This contact is determined by the use of a piece of fine screen wire (the size of the cassette) placed on the exposure side of the cassette and an exposure being made. If contact is adequate the lines of the wire will be sharply outlined over the surface of the film. If the lines are fuzzy then poor contact exists in the area that is fuzzy. These fuzzy areas must be built up by placing thin sheets of paper behind them.

The fact that the fluorescent light emitted by the fluorescent screens obeys the laws of light should be kept in mind. Consequently, dust, dirt particles, stains, etc., must not be allowed to collect on the surfaces or they will prohibit the fluorescent light from reaching the film surface and thus cause extraneous shadows in the radiographic image. To guard against finger marks and finger nail scratches the active surfaces should not be touched or handled except in washing. When the surfaces become dirty they may be washed with ivory soap and cold water by wetting a piece of clean cotton with the solution and rubbing gently. Rinse with clean water on cotton, and leave the cassette open for about 12 hours to dry thoroughly, standing the cassette on edge and draping the top with a towel to prevent dust from settling on the screens.

The second type of cassette is made of cardboard (show specimen). It is simply a cardboard envelope, as it were, and only performs the function of keeping the film away from the light until it is removed from the holder in the dark room after the exposure has been made. It never contains screens and the user has no worries about contact or dust particles etc. This holder has front side and a back side - by that I mean one side is designated as the front and must always face the tube since the other side has a lead lining in order to prevent back-scatter or stray radiation. (The same is true of metal cassettes with regard to front and back).

After the films have been exposed they are taken to the processing room for development. The first step is - place the film on a metal hangar which is a wire frame the size of the film, with small spring clips fastened in each corner to hold the film suspended in place for immersion in the solutions.

Another important film accessory is called a marker. There are many different makes and styles but they are all essentially similar in that they have various letters and numbers made of lead and usually mounted on small pieces of celluloid which are made to slip into an aluminum holder, which in turn is placed on the outside of the cassette before the exposure is made. In some instances the unmounted lead letters and numbers are used by arranging them in the proper order on a piece of adhesive tape and then applying it to the face of the film holder. Lastly, negative preservers, or film envelopes, as they are more commonly called, are used to protect the film after exposure and processing. They are made in the same sizes as films, cassettes and hangars - namely, 5 x 7, 8 x 10, 10 x 12, 11 x 14, 14 x 17 and a few other special sizes. There are many other accessories that might be mentioned but the ones here mentioned are the necessities.

THE PROCESSING ROOM

Whether or not exposed film can be manipulated expeditiously and the highest possible photographic quality in the radiographs may be obtained regularly, depends upon the proper planning of the room. The design as well as many items of equipment, and their arrangement, may vary considerably and still produce a suitable dark room, however, there are certain features which must be the same in every dark room. The first and probably most important is the feature of lightproofing. It is obviously essential that all light must be excluded from the dark room to prevent the exposure of the film during the loading and unloading of cassettes as well as during the processing of the film itself. Since it is advisable for the dark room to be located immediately adjoining the x-ray room, it becomes essential to ray proof the walls so that x-ray may not fog the films, which are in storage in the dark room. This may be done by covering the walls with sheet lead.

It is not necessary that a processing room be large. For a very satisfactory one, including a labyrinth, can be built in a space 8 x 11½ feet. It should have at least one wall, an outside wall in the building, so that by means of a window the space may occasionally be aired thoroughly. Supplementary inside, lightproof shutter or shade can be provided to exclude outside light. Processing room should be located on the shady side of the building, if possible, or at least shaded by shrubbery or trees. Since excessive heat in the dark room is objectionable, both to the operator or technician, and in the various processing steps, as well as to the stored film. It is extremely convenient, although not absolutely essential, to have a labyrinth or tunnel at one end of the room, through which it is possible for a person to enter and leave the dark room without objectionable light being allowed to enter. A film transferring cabinet or by-pass box should be built into the wall between the x-ray and dark room. This by-pass box extends through the wall with doors on either end, built in such a way that when the doors of either end are opened the doors of the opposite end may not be opened. This prevents the possibility of both ends being opened simultaneously and thus possibly causing damage to the film during the processing in the dark room. It saves a great deal of time to the operator by furnishing film without the necessity of going through the long tunnel to the dark room. Cabinets should be built into the room which will provide space for storage of films and other dark room equipment. These cabinets do not necessarily have to be lightproof, but they should be located away from the sink and developing tank to eliminate the possibility of water leaking through and spoiling the contents. It is necessary also to have benches on which the cassettes may be laid during the loading and unloading. These benches like the cabinet must be located away from the sink and the processing tank to avoid the possibility of chemicals or water being splashed on to the screens of the cassettes while they are opened. The dark room should be equipped with several dark room lights or safe lights as they are called, one of these should be located directly above the loading bench so that visibility there is good. Another should be

located over the developing and fixing tank so that observation of the film during any stage of the processing may be seen. Still another of these lights should be located on the ceiling as a sort of flood light for the entire room, so that movements about the room will not be restricted.

After these lights have been installed it is essential that they be tested so as to determine whether or not they are actually safe for x-ray film. This can be done by placing a covered film directly under these lights for a period of several minutes and then developing them to see if they have been fogged or exposed. On the loading side of the room or near the loading bench, there should be convenient facilities for developing hangars, loaded cassettes, cardboard exposure holders and the film supply. Another important thing of the dark room equipment is the film dryer. These dryers are metal cabinets into which the hangars where the film is placed are hung so that a forced stream of air blowing over coil rings in one end of the cabinet blows directly across the surfaces of the film, thus drying them thoroughly and safely. Mention has already been made of the developing tank assembly of which there are many sizes, shapes, makes, and arrangements. However, the absolute minimum requires one tank for developing solution, another tank for mixing solution, and still a third tank for water in which the film may be washed. It is important to be able to control the temperature of the chemical solution. They are usually contained as insert tanks set down inside the water compartments and thus surrounded by water. This water may be circulated through a cooling or heating system as the case may be, thus raise or lower temperature of the developing or fixing solution. It is well to have a lightproof cover fit on the top of the developing and fixing tanks, especially the developing tank. There are many smaller items which are necessary in the dark room such as thermometer,which is used to measure the temperature of the solution; an interval timer, for measuring the time of development, etc.

Any person who is given the task of designing and equipping a processing room would do well to contact any one of several companies,such as the Eastman Kodak Company, who will gladly furnish detail drawings of the processing room as well as the tank system, film bin, film transferring cabinet, drying cabinet, etc. Also much valuable information can be obtained from the representative of any reliable x-ray supply company in your locality. There are many small items of equipment and many ideas of arranging which can make the job of the technician in the dark room immeasurably easier. In finishing the interior of the dark room it should not be necessary that the ceiling and walls of the processing room be painted black, they may be of a relatively light color, a deep green for instance, provided other protective measures prevail. It is desirable, however, as to floor, benches, and walls to at least a few inches above the tanks and benches, should be thoroughly protected against the action of chemical solution and water that may be spilled or splashed on them. Kodakote paint is made especially for finishing the lower walls of the processing room, and other surfaces on which processing chemicals may be spilled, it is a glossy black, non-inflammable,

non-foggy, odorless, water proof, acid and alkali resistant, easy to apply, dries quickly and adheres firmly to any clean dry surface. If possible, the upper walls and ceilings should have a highly reflecting finish.

Dark room procedures are not difficult but they do require a certain amount of care and thoughtfulness; for instance, in the loading of cassettes care must be used that the film is not extracted from the box too rapidly as it will cause the formation of static marks on the film. Neither should the film wrapper be allowed to come in contact with the screens of the cassette, thus introducing dust, lint, and possibly dirt on the surface of the screen. The cassette should not be left open unnecessarily as particles of dust and dirt may settle on the screen or water or chemicals may be splashed across the room on them and spoiling them. After the cassette has been loaded and closed tightly, it is placed in the proper side of the pass box in such a way that it will be convenient for use of the technician in the x-ray room. In unloading the exposed cassette same care should be exercised, fingers should be dried thoroughly and finger nails should not be used to dig out the corner of the film as this will probably lend to marring or scratching of the screen. As soon as the film is removed the lid of the cassette should be allowed to close and the film immediately placed on a hangar. This is done by first attaching one edge of the film to the two bottom clips, then attaching the two spring clips at the top of the hangar. The film is now ready for emersion into the developing solution.

There are two types of developing - one is called "time temperature" development and the other is called "sight development". In time temperature development the film is emerged in a developing solution the temperature of which is known, for a measured length of time, depending upon the temperature of the solution. In "sight" development the film is emerged and watched until fully developed and then removed. The former method is the method of choice. This standardized time temperature procedure is important because the chemical reaction should take place within a very limited time and temperature ranged. If it is not carefully observed the effects of even the most accurate exposure technic will be nullified and the latitude inherently characteristic of all films will compensate any slight errors made in estimating the exposure factors, but no film is capable of withstanding the effect of errors through the "guess" method in processing. As stated before, modern x-ray films consist of a special emulsion - a gelatine that contains a silver halide compound - coated on a cellulose acetate support in layers about 1000th of an inch in thickness. When the film is subjected to x-ray a change takes place in the silver halide salt so that those which have been exposed to the rays are capable of being converted into another form of silver through the action of a chemical solution, called developer; those that are unexposed can be removed by additional chemical treatment, called fixation.

4. The Processing Room

Processing represents the various steps - developing, rinsing, fixing, washing, and drying - which bring about the chemical changes that render visible in the radiographic image the latent image created by the x-ray. The essential constituents of this developing solution includes elon and hydroquinone;these are the reducing agents which, under proper division, select those granules of the silver halide which have been sensitized by the x-ray or other factors, and they convert these granules into metallic silver. Elon is not very penetrating. It acts on the superficial layers of the emulsion, the hydroquinone, though acting more slowly, is more penetrating. Other constituents include sodium sulphite which serves to counter-act oxydation of these agents; bromides which serve to restrain the reducing agent, and thereby provide for more uniform effect, lessening the likelihood of the chemical fog; and an alkalizing agent such as sodium carbonate which serves as a catalyst for the reducing agent.

Having a fresh developer the ordinary time requirement for development is based on 5 minutes and 65° F. If it is found that the developing solution is at a higher temperature than 65° a shorter length of time will be necessary in development. If, however, the dissolving solution is at a temperature below 65° it becomes necessary to increase the time of development. Satisfactory temperature range the developing solution is ordinarily considered as from 60° F. to 70° F. above or below this temperature satisfactory radiographs will not be produced. After the given developing solution has been used for a little while it will be necessary to lengthen the time of development at the various given temperatures, owing to the weakening of the solution through use and oxydation. After development the film is washed for 10 or 15 seconds in circulating water and then placed in the Hypo or fixing bath. There are two reasons for this intermediary washing:

1. The developer is of alkaline reaction, while the fixing bath is acid. Rapid change over in the case of fresh solution is likely to produce fogging of the emulsion.

2. A large film may carry over as much as one ounce of solution. Repeated admixture of the developer into the fixing bath will not only result in diluting the latter but also directly weakening it.

When leaving the developer the gelatinous emulsion of the film is sought both because of the effect of water and because of the alkalinity. The purposes of the fixing bath are to:

1. Remove those granules of the silver halide which were not sensitized and, therefore, not acted upon by the developer.

2. Harden the emulsion.

The first of these functions is accomplished by sodium thiosulphate, while the second function is performed by the alum. In addition, the fixing bath also contains sodium sulphite again serving to counter-act oxydation. And an acid such as glacial acetic, or sulphuric, which serve to stop all further development. Film should be left in the fixing bath for from 3 to 10 minutes depending upon the freshness of the solution. Film manufacturers claim fixation is complete when the film is left in the solution twice the length of time it takes for the film to clear. They should then be placed in the bath of circulating water for not less than 15 minutes. Within complete washing the film when dried will show either a thin coating of white crystal material or it will appear foggy. After the washing period the film will be hung over a draining pan, as a rule, where the surplus water is allowed to drain free after which it may be hung in the film dryer for drying.

Standardized time temperature developments can be followed throughout the life of the solution by the use of the x-ray developer exhaustion charter. This charter embodies a pad on which the exact number of films that have been processed can be indicated in code. Development intervals can then be increased at just the proper time. This record will also indicate the proper time to discard the old solution and replace it with new. A copy of this chart can be usually obtained from your x-ray supply company without cost. It always should be kept in mind that it is most inadvisable to continue the use of the developer beyond the exhaustion limit shown on the chart, moreover the developer should be checked frequently even though the chart is exployed. Exposure of the solution to the air and high temperature and dilution with water excellerates the aging process and hence shortens its effective life. Weak solution causes changes such as lack of detail, weakened image, etc. Owing to sensitiveness of x-ray films, cleanliness is of great importance in processing procedure. It is imperative that the processing room as well as the accessories and equipment be kept scrupulously clean and that they be used only for the purposes for which they are intended. Any chemicals that are spilled should be wiped up immediately so they will not have a chance to dry, get into the air, and later settle on the film surface causing spots. Thermometer and developing hangars should be thoroughly washed with clean water immediately after being used, otherwise solution adhering to them will dry and possibly cause contamination or streak radiogram when used again. Importance of the film processing room is too seldom appreciated. It has been estimated that 80 - 90% of the trouble which occur in an x-ray department can be found there. It is there that intensifying screens are rendered defective because of foreign material falling upon their surfaces, improper fixation, or because of mix imposed upon their surfaces, with frequent replacements they become a most expensive item in the department.

FORMULA FOR DEVELOPER

Elon	60 grams	(for tray development use 1/24 as much)
Sodium sulphite	2500 grams	
Hydroquinone	240 grams	
Sodium carbonate (dessicat)	1250 grams	
Potassium bromide	150 grams	
Cold water - to make -	24 liters	

(average time of development - 5 minutes at 65° F (18° C.)

Weigh out the individual chemicals on small pieces of clean paper.
Mix in white enamel containers.
Dissolve them individually in as small a volume of hot water as possible at 125° F.
Mix a handful of dry sulphite with the dry Elon and Hydroquinone before dissolving them.

1. Pour together the solutions of the Elon and the Hydroquinone.
2. Pour together the solutions of the sodium sulphite and sodium carbonate.
3. Add the potassium bromide solution to the soda solution just mixed.
4. Add the Elon and Hydroquinone mixture to the mixture of soda and bromide solutions.
5. Add cold water to make --- the necessary volume.
6. Filter each solution before mixing thru 6 thicknesses of gauze.

TIME - TEMPERATURE DEVELOPMENT

63° F.	7	minutes	development.
65° F.	5	"	"
68° F.	4	"	"
70° F.	3.5	"	"

FORMULA FOR FIXING BATH

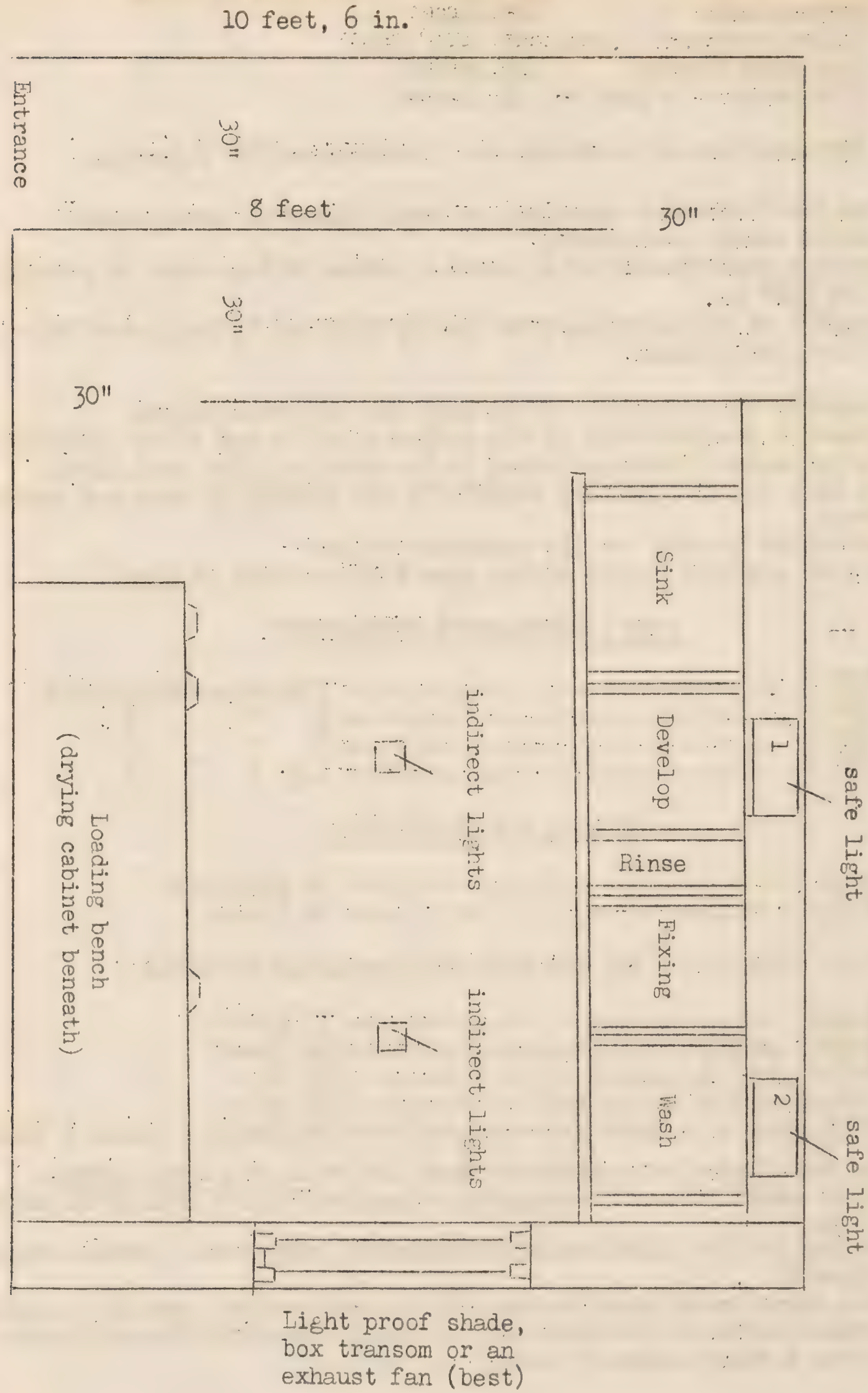
Hypo	20 kilograms
Water - to make	48 liters

When fully dissolved - add the following hardening solution:

Water	12 liters
Sodium sulphite	900 grams
Acetic acid (glacial)	780 cc.
Potassium Alum (granular)	900 grams
Cold water - to make	24 liters - totals - 72 liters

1. Dissolve the chemicals in water at about 125 F. <u>in the order given</u>.
2. The sodium sulphite must be completely dissolved <u>before</u> adding the acetic acid.
3. Add the alum to the sulphite-acid solution and stir until a clear solution appears.
4. When this clear sulphite-acid-alum solution has cooled - add it - slowly - with stirring to the cool and thoroughly dissolved hypo solution.
5. Filter thru 6 thicknesses of gauze.

7. The Processing Room



FLOOR PLAN OF DARK ROOM

R/5

CHEMISTRY OF THE DARK-ROOM

A developing bath is composed of a mixture of solutions of:
- Metol - or its equivalent
- Hydroquinone
- Sodium Sulphite
- Sodium Carbonate
- Potassium Bromide

Metol or Elon is a developer which separates the silver from silver bromide that has been exposed. It is very slow without the presence of hydroquinone. It does the developing of the first minute. This developing chemical brings out the detail very quickly.

Hydroquinone is a developer which starts developing in the second minute and does the developing from then on. It will not act below 45' F - above 70' F it acts too well and will act on silver bromide that has not been exposed - thereby causing chemical fog. Hence the reason for keeping the developing solution between 63 and 70' F. It helps contrast but does not bring out detail very well.

Sodium Sulphite is a preservative because it captures any free oxygen that is present. Free oxygen oxidizes and destroys the developing chemicals.

Sodium Carbonate is used to render the developing solution alkaline, since the process of developing can take place only in an alkaline solution.

Potassium Bromide restrains the chemical action of developer which otherwise would be too rapid.

A fixing bath is composed of a mixture of solutions of:
- Sodium Thiosulphate - (hypo)
- Sodium Sulphite
- Acetic, or Sulphuric acid
- Potassium, or Chrome Alum

Hypo removes the unexposed and therefore the undeveloped silver bromide.

Sodium Sulphite again is used to capture any free oxygen. In this case oxidation of the fixing bath results in a brownish stain of the negatives.

Acid neutralizes the alkaline developer and thereby stops further development.

Alum is used to harden the soft and swollen gelatin.

There are four main factors concerned with adjustment of the x-ray machine for the making of an x-ray negative. Their functions or their effects upon the film are not separate and distinct but are widely overlapped, and one who has learned to evaluate these factors and to recognize their proper balance will have learned the basis for x-ray technique. Because of the very nature of variability of these factors it is impossible to learn much about them without actually seeing and studying their effects in hundreds of films. These four factors are: Milliamperes, Time (in seconds), Kilovolts, and Distance.

1. Milliamperes. Is an expression of the quantity of x-ray being produced and is controlled by the filament circuit as that circuit controls the heat of the filament. This factor might be called an exposure factor since it effects the density of the film. If 10 milliamperes is used in one exposure and 20 milliamperes in another of the same part and with all other factors remaining constant the latter will be twice as dark as the first. That is, the second film will have received twice as many x-rays as the first and will therefore have twice the exposure. If then, one wishes to double the generalized blackness of a certain exposed film one could use the technical factors used for the first film with a change in the milliamperes to twice the value first used. In other words, double the milliamperes and you double the density (generalized blackness) provided, of course, all the other factors remain constant.

2. Time. (Length of exposure in Seconds) - It is impossible to express the amount of exposure given to a film by simply stating the milliamperes used, any more than it is possible to give the amount of water delivered by a certain pump by saying that it pumps 50 gallons per minute. There must be an expression of time. In the case of the pump the number of gallons flowing per minute must be multiplied by the number of minutes the pump operated to determine the quantity delivered. If it operated 10 minutes then 500 gallons would have been pumped. This same relation exists between milliamperes and seconds. The product of the length of the exposure (in seconds) and the milliamperes used is a figure representing the total quantity of exposure and is called Milliampere Seconds and is abbreviated MAS. It can be said, then, to double the density produced by a given technique one can double the MAS. This can be accomplished most easily by either doubling the time or the milliamperes.

3. Kilovolts. Controls the quality of the x-ray beam in that a variation in the kilovolts results in a variation of the x-ray wavelengths. The higher the kilovolts the shorter the predominant wavelengths and the more penetrating the rays. An increase or decrease of the kilovolts, then, will vary the quantity of x-rays which reach the film through the part being exposed. In this way kilovoltage effects the density of the exposed film. It can be said that an increase in 10 K. V. (Kilovolts) results in a double density. In other words, an increase of 10 K. V. results in a shortening of the x-ray wavelengths sufficient to increase the total penetration so that twice the amount of rays actually reach the film. It now becomes apparent that density is controlled by two factors, MAS and

KV. Each of these has its own special effect on the film, MAS being responsible for contrast and KV tending to modify contrast. The selection of these factors for purposes of radiographing any particular part is made more or less arbitrarily and vary considerably in technique charts produced by different persons. In general the principle to be followed is to use a kilovoltage which is adequate to penetrate the part to be radiographed and a corresponding MAS to give the proper density to the film. Occasionally it is necessary to depart from an otherwise suitable technique such as in the case of radiographing children who are too young to cooperate by remaining motionless during the exposure. It will then be necessary to alter the standard technique so that the exposure time will be short enough to preclude ruining the film because of movement during the exposure. A later section will deal with changing of exposure factors.

4. Distance. The distance from the target of the x-ray tube to the film greatly influences the amount of radiation received by a given area of the film. This results from a spreading of the x-ray beam from its source on the target just as the rays of light from a flashlight spread to cover a larger and larger area as the flashlight is moved further and further away. The law governing this spreading of the beam of rays is stated as follows: The density produced by a given x-ray beam varies inversely to the square of the distance. In other words if it were necessary to double the distance, and still keep the same photographic effect on the film, the exposure would have to be increased four times. If the distance were shortened by one half, the exposure would have to be shortened to one-fourth of the original. In everyday use the technical factors for radiographs of the various parts of the body are selected on the basis of a focal-film distance of from 30 to 36 inches. That is, if 33 inches is taken as standard then that distance is used for practically every part of the body and the rest of the exposure factors are based on that distance. The notable exceptions are radiographs of the chest and lateral cervical spine, which are made at 72 inches. The selected distance is kept constant in so far as is possible, but in certain instances where a slight change is necessary a correction for the resulting change in density of the film may be offset by adding 1 KV for each inch increase or subtracting 1 KV for each inch decrease. This 1 KV per inch relationship holds true only for relatively short changes in distance and in any case probably not more than 8 or 10 inches.

Radiographic Density Equivalents

1 inch distance	=	1 KV
Double time	=	Double density
Double M A	=	Double density
Double MAS	=	Double density
Add 10 KV	=	Double density

XXI. RADIOGRAPHIC QUALITY AND FILM ANALYSIS

The many things which effect radiographic quality can be analyzed in terms of four main characteristics. The first of these is Distortion. It can be defined as the perversion of true shape of the radiographed part. Distortion can be further divided or classified in terms of the results seen on the film. All distortion is the result of magnification which, in turn, can be of two types. 1, Equal magnification and 2, unequal magnification. In the former the film image is larger than the part and is the result of one of two things; 1, too great part to film distance; 2, too short a distance from tube to part. The latter, unequal magnification, is the result of malalignment of the tube in relation to the part or the film.

Detail - The sharpness of contour and structural lines. It decreased by -

(1) Distortion
(2) Movement of the part, the film, or the tube.
(3) Larger focal spot.
(4) Use of an intensifying screen.
    a. The faster the screen the greater the loss of detail.
(5) Poor screen-film contact.
    a. Poor screen contact can be checked and definitely located by placing an ordinary piece of window screen over the face of the suspected cassette and making a short exposure. Upon viewing the developed film areas of poor contact will be slightly darker and the lines of the screen wire will be fuzzy and rather indistinct. Areas of good contact will show sharp screen wire lines.

Contrast - The relative degree of blackness of the black portions of the film as compared with the whiteness of the white portions, that is, the abruptness of change from black to white in the gradation of densities. Contrast is decreased by -

(1) Use of a film of which the emulsion has a long scale gradation.
(2) Increasing the kilovoltage.
(3) Using slow types of intensifying screens or cardboard holders rather than screens.
(4) Secondary radiation, which is increased in proportion to the thickness of the part and increases in kilovoltage. The maleffects of secondary radiation might be reduced by the use of grids, cones, or diaphragms.
(5) Overexposure and shortening in the time of development or the use of cold developer.
(6) The use of hot developer - above 70°.

Radiographic Density - The generalized blackness of the exposed portions of the film. Density is increased by -

(1) Time and milliamperage increases (MAS). These bear an almost direct proportion to the density.
(2) Kilovoltage - in proportion approximately as the squares of the relative kilovoltages. Roughly 10 KV = double density.
(3) Excessive development time or hot developer.
(4) Decrease in focal film distance. (Inverse square law)

Radiographic density is decreased by -
(1) Increase in distance.
(2) Use of grids, cones or diaphragms - unless KV, time or MA is increased.
(3) Change from screen to cardboard holder without compensating with other factors.

The perfect x-ray negative would be one which displayed a perfect balance of technical factors, a minimum of distortion, a maximum of detail, with just the right amount of contrast and radiographic density. That such a film is not always easy to produce is easily appreciated when one sees all the many factors which have a definite effect on one or all of the required elements of perfection. The first step in mastering these obstacles is to learn to recognize them quickly in a film. Secondly, to know their cause or causes and how to correct them. This knowledge can only be obtained through experience under supervision.

XXIII. PRINCIPLES OF ROENTGEN THERAPY

We know that one of the physical properties of x-ray is that it causes a biological change in living cells and tissues. As far as we know, this change is due to the destruction of cells and the reaction of the body to this destruction of cells. No other action of x-ray upon living tissue has been proven. The ultimate effect of this cellular destruction can vary tremendously, however, depending upon the amount and the rapidity of administration of the radiation, the relative sensitivity of the cells involved, and the type and function of tha cells.

There are two large groups into which most of the types of cases treated by Roentgen Therapy fall. These two groups are: 1. Malignancies; 2. Infections. When treating malignancies we administer tremendously large doses of x-ray in an attempt to destroy the cells of the tumor as well as the cells of the small blood vessels in the tissue around the tumor hoping that the scarring of these small blood vessels around the tumor will shut off the blood supply to the tumor causing it to regress, as well as shutting off one of the avenues for metastasis or spread of the tumor to new areas. When treating infections we use comparatively small doses,not attempting to kill the organisms causing the infection, but in an effort to help the body to control the infection. The mechanism by which this is accomplished may be by disintegrating the cell membrane of the white blood cells which have mobilized in the region of the infection allowing the antibodies (agglutinins, lysins etc.) to act upon the organisms more quickly and effectively, or it may be, especially in the more chronic type of infection, that it again acts upon the cells of the small blood vessels increasing the resistance of the tissues to the infection.

Some of the types of malignancies which are commonly treated by x-ray therapy are: carcinoma of the breast (either a pre-operative or a post-operative series with surgical removal. Preferably both); carcinoma of the cervix of the uterus (in conjunction with Radium Therapy); carcinoma of the skin; carcinoma of the mucous membranes; Leukemias; Lymphoblastomata; and many others. In some of these cases, particularly carcinomas of the skin and cervix uteri, radiation therapy gives excellent results if started reasonably early. In too many cases, however, the results are only fair or even poor. It is for this reason that most authorities feel that in spite of the terrific progress we are far from the solution of the problem.

The infections which are more commonly treated by x-ray therapy are: furuncles and carbuncles (boils),particularly about the nose and face and in the external auditory canal; cellulitis or erysipilas; chronic infections of the skin; and gas gangrene. X-ray technicians can ignore everything that has been stated so far and remember gas gangrene. The importance of this infection was emphasized during the first stage of the world war from 1914 to 1918 in which a very high percentage of war wounds became infected with gas gangrene and a great many of those that became infected died from the infection. The experience was repeated, on a smaller scale, on Bataan Peninsula from January until April 1942.

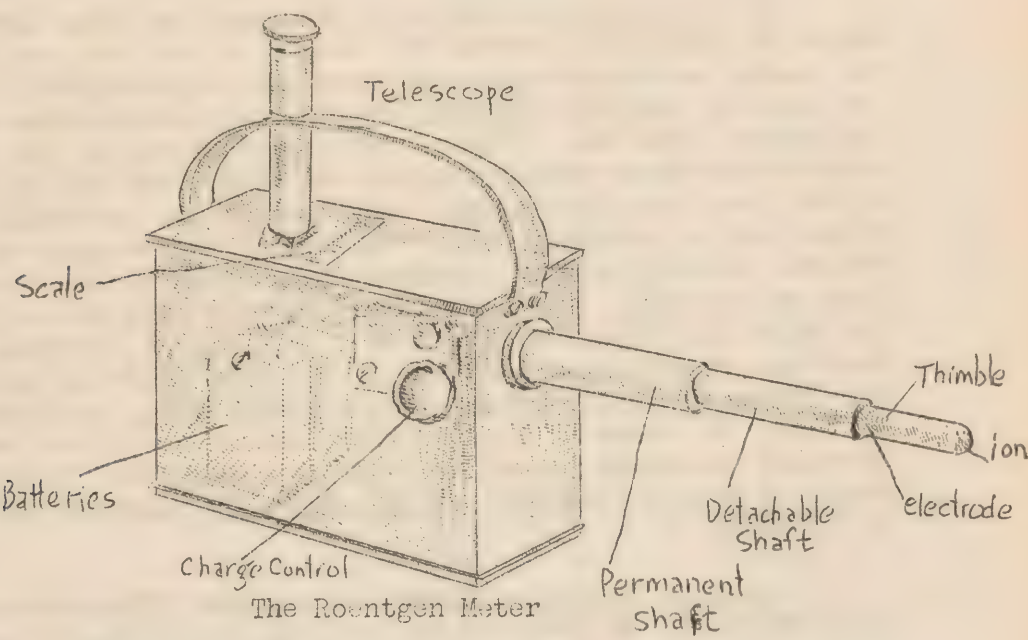
Gas Gangrene is an infection caused by an organism called the Bacillus Welchi or the Bacillus Perfringens. It was discovered about 1900 by a Dr. Welch. The Bacillus Welchi is an anaerobic bacterium, which means that it can multiply and grow only in a suitable environment which has a relatively low concentration of oxygen. In other words, in its active form the bacteria grow in deep, penetrating wounds where there is little or no contact with the air. When in an adverse environment the bacilli change into a "spore" form which has a hard crust around it. When in the spore form the bacteria are very resistant to heat, cold, dryness or high oxygen concentrations. These spores are found in dirt and manure so that when a soldier is forced into very close contact with the ground to stay out of the way of bullets, it is only natural that he should accumulate many of these spores on his clothes ready to be carried into a wound.

The reason that the infection is called "gas" gangrene is that when the bacteria multiply in the tissues they produce considerable quantities of a very foul, putrid smelling gas which can be seen in the tissues very early by x-ray examination later, it can be felt as crepitation (a sensation similar to crinkling crepe paper in your hands) then when the distinctive odor is noted there is no question as to the diagnosis.

Some may wonder why we are concentrating on gas gangrene to you who are technicians, not doctors. The reason is that we feel that you may be attached to a unit, possibly a mobile surgical hospital, that may be very close to the combat area where you will be receiving casualties within a few hours of the time of infliction. That is the time that x-ray therapy should be given for gas gangrene. It may be that the doctor who is in charge of the x-ray in your unit has done a great deal of work in diagnostic procedures but has not had experience with therapy. If so, and he should ask you if you know the technical procedure for administering x-ray therapy for gas gangrene, we want you to be able to say "yes". Then be able to carry out the procedure safely, efficiently and confidently. It should never be up to you to decide whom to treat and if there is a Radiologist who has had experience and tells you how he wants the treatments administered, you must certainly follow his instructions. This instruction is intended for use in emergencies only.

In administering Roentgen Therapy it is absolutely essential to have a means of measuring the dose to be given, both as to the <u>quantity</u> of radiation to be given and the <u>quality</u> of the radiation used. The unit of quantity if roentgen therapy is the <u>roentgen unit</u>. The roentgen unit is an arbitrary unit of measurement of quantity and is used much the same as a quart is used to measure milk or any other liquid; pound is used to measure solids; feet to measure distance or length, etc. The roentgen unit is rather small and the quantity used in a single dose may vary from 50 to several thousand, depending upon the quality of radiation and the effect desired. With the quality of radiation produced by the Picker Field Unit at 100 K.V. when treating an infection the dose might vary from 50 to 100 r (roentgens) with a safe margin.

The quantity of radiation as measured in "r" or roentgens is determined by the use of a roentgen meter to calibrate the output of the x-ray machine at any given set of factors so that any desired quantity may be obtained and the dosage accurately re-duplicated. The roentgen meter functions upon the principle of another of the physical properties of x-ray, i.e. the fact that any gas through which x-ray passes is ionized in direct proportion to the quantity of x-ray passing through the gas. It consists of a thimble made of horn containing a definite, measured amount of air, and connected to a set of batteries in such a way that an accurate charge of ions can be applied across this air. When the air is not ionized and is neutral, no charge will pass across this air. When x-ray is passed through this air, however, a definite number of ions will become discharged depending directly upon the amount of x-ray which passed through the air. The amount of this discharge is read upon a scale in the system which is calibrated to read directly in roentgen units (r). Thus we can measure directly the number of roentgens per minute produced by the machine with a given set of factors and can re-duplicate this output at will by accurately reestablishing this set of factors.



The Roentgen Meter

In considering the quality of radiation delivered, we must think of a great many factors which determine the effective wavelength of the x-rays produced. These factors are: Kilovoltage; Filtration; and Distance. The kilovoltage is first because this determines the wavelength of the x-rays given off from the target of the tube. The higher the kilovoltage, the shorter is the resulting wavelength. X-ray machines are manufactured to generate x-rays with widely varying kilovoltage ranges, each machine having its own particular use. Some machines range only from about 30 K. V. to about 85 K. V. These can be used only for diagnostic purposes, and even in this field they are somewhat limited. Others

have a range of 40 K. V. to 140 K. V. and they can be used for all diagnostic purposes as well as for Superficial Therapy. Superficial Therapy is considered to include from 80 to 140 K.V. and some machines are made with this specific range for use in the therapy only, not for diagnosis. The deep X-ray therapy machines are usually constructed to generate around 200 to 250 K. V. This is the type of machine used at Letterman General Hospital and so far seems to be the most commonly used. The next step is to the equipment which generates from 400 to 500 K. V. Not many years ago these machines were in the purely experimental stage and were available as custom built equipment only. Recently, however, they have been placed in routine production and are gaining rapidly in popularity. These are called Super Voltage Therapy machines as are the experimental machines constructed to generate 800, 1000, and 1500 K. V. respectively. It has not been definitely proven that x-rays of extremely short wavelength, i. e. generated with kilovoltages in excess of 400 K. V. are any more effective than those which are generated with the 200 K. V. machines, but there are many radiologists who are of this opinion.

By Filtration we refer to the metal or other material which is interposed between the target of the tube and the patient to absorb the "soft" x-rays of very long wavelengths. Filters are usually made of aluminum, copper, or a combination of aluminum and copper plus tin. Filters are always placed in the machine with the heaviest filter nearest the target and the lightest filter away from the target. That is, if you are using both a copper and an aluminum filter the copper filter goes on top (nearest the target) and the aluminum filter goes on the bottom (away from the target). In Superficial Therapy with 80 to 140 K.V. the usual filtration varies from 1 to 3 mm. of aluminum, depending upon the amount of penetration of the skin which is desired. If the lesion is right on the surface of the skin, no filter would be used. If there is considerable induration of the lesion and it seems to extend several millimeters deep, then 3 mm. of Al. would be used or possibly a $\frac{1}{4}$ MM. of copper added to the 3 mm. of aluminum.

In Deep Therapy considerably greater filtration is used. With 200 K. V. the usual filter is from $\frac{1}{2}$ to 2 Mm. of copper plus 1 Mm. of Al. With the Super-Voltage Therapy from 3 to 5 Mm.of copper plus aluminum is usually used, but considerably more filtration than this is used by some radiologists. The advantage in using this high filtration factor is to absorb all of the radiation except the very shortest wavelengths so that relatively much more of the radiation reaches the lesion which may be as much as 8 or 10 centimeters from the surface. This is called increasing the Depth Dose at the level of the lesion. The Distance is important for it not only helps to control the quantity of radiation as explained by the "inverse square law" in which the "quantity of radiation is inversely proportional to the square of the distance" but distance also acts somewhat as additional filtration, allowing only the shorter waves to reach the skin and increasing the depth dose.

Filters are also used to measure the quality of radiation using any given set of constant factors. Instead of measuring the wavelength of a given x-ray beam by means of the complicated "grating method", we estimate the effective wavelength of the beam by actually finding out what the beam in question can do. That is,we find out how much it can penetrate without being completely absorbed. The technique by which this is done is as follows: The machine is set at the factors which are to be tested, i. e. on the Picker Field Unit the prescribed factors are 100 K. V. and 4 M. A. at 12 inch distance; make multiple readings with the Roentgen Meter starting with no added filter and progressing by $\frac{1}{4}$ mm. Al. steps up to a total of 5 mm. of Al. Enter the average values on a graph using Roentgens per minute as ordinates and millimeters of Aluminum as Abscissae; determine by means of this absorption curve how much filter was required at any given point to reduce the quantity of radiation by a half; This gives you the Half Value Layer for the radiation at that point and this half value layer is an excellent, workable measure of the Quality of that radiation, for the larger the half value layer is, the shorter the effective wavelength of the radiation, the more penetrating the quality of the radiation and the greater the depth dose.

Absorption Curve

As is true with most scientific subjects, the best way to know your machine's output, both as to quantity and quality, is to calibrate it again yourself with the Roentgen Meter and to chart its absorption curve at various distance and filter factors. If you do not have access to a Roentgen Meter, however, the next best thing is to know how to read the chart, either in your notebook or in the instruction manual of the field unit and to use its facts wisely. You will see there some precautionary measures

concerning individual and total dosages you may administer with safety. Remember these rules well, for as was mentioned previously, it will take only one bad x-ray burn to impress the importance of these rules indelibly upon your minds, BUT - we don't want you to have to have that one burn, so be infinitely careful.

You see on the chart that with the given factors of 100 K. V., 4 M.A., 12 inch distance and 2 millimeters of aluminum filter that the Picker Field Unit (and this machine alone, no other) delivers 18 r (roentgens) per minute to the skin. You are given there the exact technique to be followed in cases in which there is a probability of infection with gas gangrene and a technique to follow in cases in which gas gangrene has been diagnosed. Follow these instructions carefully unless you have personal instruction from your radiologist regarding a different procedure.

ROENTGEN THERAPY

Roentgen therapy can be accomplished with the Army Field X-Ray Machine using a milliamperage of four kilovoltage of 100.

Use foot-switch at the greatest distance from the X-Ray tube and patient. The r-output is as follows:

The Tube has a built-in filter of $\frac{1}{4}$ mm. aluminum.

Focal-skin Distance	Built in Filter $\frac{1}{4}$ mm.	Built in Filter Plus 1 mm. Aluminum	Built in Filter Plus 2 mm. Aluminum	Built in Filter Plus 3 mm. Aluminum
8"	107	60	42	31
10"	68	37	26	20
12"	48	26	18	14
16"	26	15	11	8
Half Value Layer	1.25 mm.Al.	2 mm. Al.	2.50 mm. Al.	3 mm. Al.

This quality of x-radiation should be administered only for infectious lesions. Any one treatment should be limited to 75 r. The total dosage should never exceed 400 r.

ROENTGEN THERAPY FOR GAS GANGRENE

PROPHYLACTIC TREATMENT for severe wounds, no definite diagnosis of gas gangrene has been made and no symptoms demonstrable.

Focal-skin distance of 12-inches, using 2 mm. aluminum filter, 100 K.V.P. and 4 M.A. (18 roentgens per minute) for five minutes by a stop watch.

THERAPY FOR GAS GANGRENE in which the symptoms and diagnosis is definitely established (i. e. crepitation, odor, x-ray films).

Use same factors as above (12-inch distance, 2 mm. filter, 100 K. V. and 4 M.A.) for four (4) minutes, twice a day, morning and afternoon, for four or five days.

XXIV. ROENTGENOGRAPHIC PROCEDURE

In order to get the best diagnostic results possible the x-ray technician must follow a certain procedure on every film that is taken. Whether he follows this procedure unsciously by force of habit or whether it is done methodically, the steps are the same. Moreover, in either instance, the steps should follow in the same order so that the best results can be obtained with the greatest possible speed.

There are twelve main steps that must be taken into consideration for every film that is taken. Many of these are done without thinking by the technician, but nevertheless they are done for every exposure that is made. These steps are as follows:

1. Determine the object of the examination and decide what positions should be used to give the desired information.

    a. Object of the examination is usually given with the order.
    b. If, due to injury, etc., the patient cannot assume a standardized position for the examination, the technician must be capable of getting diagnostic results by using an unorthodox procedure.

2. Decide whether or not to use the Bucky-diaphragm.

    a. The thicker the part the more secondary radiation given off when penetrating the part. The Bucky is used to stop much of this secondary radiation from reaching the film.

3. Select proper size cone.

    a. The size of the cone is governed by the size of the film and should be small enough to limit the area of exposure to the film size.

    b. The extension cone (or spot cone) is used in special examinations where maximum detail is desired of a small area of a given part, such as: Sinuses and mastoids (within the skull), individual articulating surfaces (lumbo-sacral, acetabulum, patella, etc.)

    c. If cones are not available a port should be substituted and the same rules for size will apply.

4. Decide whether to use a screen or cardboard. Place film and apply identification marker.

5. Determine the target to film distance and set the tube at that distance.

    a. Dependent upon focal spot size and output of tube.

    b. After a reasonable distance has been decided upon, keep it constant.

2. Roentgenographic Procedure

(1) Reasonable distances: 30", 33", 36", or even 40".

c. For extension cone shots - use the length of the cone.

6. Measure the part and attempt to estimate the tissue density.

a. The more muscular the individual the more penetration will be necessary.

7. Determine the kilovoltage to be used.

a. The amount of KV necessary to penetrate the part and yet keep the secondary radiation at a minimum.

8. Determine the milliamperage to use. (Shown on the technique chart.).

a. Consider the tube rating chart. (When setting up the technique chart).

(1) Use the highest MA which the tube can easily withstand on the smallest focal spot compatible with length of exposure.

(2) Use an MA that can be left constant for most parts of the body.

(a) Change it only for special circumstances.

b. When using fluoroscopy.

(1) Use 3 to 5 MA dependent upon how much is necessary to get contrast.

(a) The lower the MA the longer exposure is permissible.

9. Determine the time to be used.

a. Dependent upon the type of film holder being used.

(1) Screens or cardboards.

b. Consider the photographic effect and possibility of movement and balance the two factors.

10. Set the machine.

11. Position the patient.

12. Make the exposure.

a. Watch the meters to see that the machine is working properly.

There are two more steps that may come under the jurisdiction of the technician. These, however, are dependent upon the size of the laboratory. If it is small the following two steps are also necessary.

13. Develop the film.

14. Analyze the film as to its diagnostic qualities and retake if it is necessary. If it is all right, release the patient.

    a. The patient should not leave until steps 13 and 14 are completed in all cases where it would be impractical to get him back.

XXVI. SPECIAL RADIOGRAPHIC PROCEDURES INVOLVING MECHANICAL PRINCIPLES

STEREOSCOPY PLANOGRAPHY KYMOGRAPHY

STEREOSCOPY.

The work stereoscopy is derived from two root words, stereo-pertaining to space relationships, and scopy-pertaining to the sense of vision or sight. Stereoscopy then, is the visualization of the relative positions of objects in space. In the field of Roentgenology stereoscopy refers to the perception of the relative positions of the structures which were responsible for the images on the film giving the observer a sense of perspective, or, as it is commonly known, the stereoscopic effect.

In ordinary sight stereoscopy is accomplished by binocular vision with a substantial interpupillary distance of about $2\frac{1}{2}$ inches. This arrangement functions in a similar manner to the common range finder used on many cameras. Just as true stereoscopy is impossible with one eye, so is true stereoscopic effect impossible with a single film. True Stereoscopic effect is accomplished by taking two exposures on separate films with exactly the same object-film relationship but with a shift of the tube to simulate the interpupillary distance of the eyes.

Stereoscopic films are studied by means of stereoscopic view-boxes so constructed by the use of mirrors that the left eye sees one film and the right eye the other. Most of these boxes are constructed so as to have about 25 inches from the mirror to the film and since you will remember that the interpupillary distance is $2\frac{1}{2}$ inches, the latter distance is about 10% of the former. It is important to maintain a corresponding relationship of the tube shift distance to the tube-film distance. Thus in stereoscopic examination of the shoulder using a 30 inch tube-film distance, the tube shift will be about 3 inches. In a stereoscopic examination of the chest using a 72 inch tube-film distance, the shift of the tube between the films comprising the stereo pair will be about 7 inches.

It is desirable to place on stereoscopic films, besides the ordinary markers used routinely, an arrow to indicate the direction of the tube shift and a number to show which of the two films was taken first. This procedure will help the radiologist a great deal, not only in putting the films in the stereoscopic view-box properly for study, but also in selecting stereoscopic pairs from a large number of single examination films previously taken on the same part, or several single films made on the same part the same day.

Stereoscopic studies are very helpful to the radiologist in establishing diagnoses concerning structures in which satisfactory projections at right angles are difficult or impossible to obtain. In many laboratories the radiologists require stereoscopy for even routine examinations of shoulders, hips, pelves, sacra, mastoids, sinuses and skulls. If there is ever any question concerning the presence or absence of tuberculosis of the lung in a single film examination of the chest, a stereo is requested.

2. Special Radiographic Procedures Involving Mechanical Principles.

The principle which we attempt to follow in deciding the direction for the tube shift is that the shift should be across the long axis of the important bones involved. This rule is easy to follow in examinations of the extremities, obviously we would shift the tube across the arm rather than along the length of it. It is not always this easy, however, for in many instances, such as the skull, shoulder and others, the important bones are about as broad as they are long. In these instances the direction of the shift is unimportant as far as the part is concerned, so the direction of the shift is arbitrarily chosen by the radiologist or is determined by mechanical factors such as the relationship of the axis of the grid lines of the Bucky to the tube shift. When possible, it is better to shift with the Bucky grid lines rather than across them because of the tendency to "cut out" when the shift is made across the Bucky grid lines. If a cone is used, it is very important to remember that the tube must be tilted toward the film from the extreme excursion of the shift, both ways toward the center, otherwise the projection will not be centered on the film.

PLANOGRAPHY (Synonyms- Stratography, Tomography)

This special procedure is based upon the principle that to obtain detail in a radiographic image the object must maintain a constant relationship to the roentgen beam. In routine radiography we feel that the object must be immobilized properly, the tube must have adequate support so that it will not vibrate and the film must remain still. When these conditions are established we feel that there will be a constant relationship between the object and the roentgen beam and we can expect maximum detail consistent with the technical factors used. If this relationship is not maintained throughout the exposure, however, there will be loss of detail and a blurring of the image.

In a relatively thick part, such as the skull or chest, there are often times in which we are interested in one particular area or cross section of the part, yet the detail of the area in which we are interested is lost by the superimposition of detail of thicker or more dense parts. By blurring the detail of these thicker parts and maintaining the detail of the cross section in which we are interested, we are able to analyze this area more accurately and to see detail otherwise obscured. We obtain, in effect, a film similar to that which we might obtain if we were able to take a slice about an inch thick from the part at the level in which we are interested and place this slice on the table for roentgenography. If we are not quite sure what level we are interested in, we can make serial films of the part which might be comparable to making many slices of the part and projecting each section on separate films.

The mechanical principles upon which the planograph is made and functions may be explained as follows: (Sante) "If an x-ray tube, mounted on one end of a rod is centered to an x-ray film mounted securely on the other end, then the rod may be revolved or oscillated about any fixed point without disturbing the centering of the tube to the film. If any stationary object to be roentgenographed is

interposed between the tube and the film, then the structures at the level of the point of oscillation will not change in relationship to the tube and film, and will be clearly shown in the roentgenogram; all other structures will constantly change in the relationship to the tube and film and will be blurred. Now, if by a mechanical device it is possible to make the tube and film glide along horizontally in fixed planes at their respective levels, the shadows cast by every point in a thin layer of tissue of any object interposed exactly in the plane of oscillation between the tube and the film will remain clear and all other points will be blurred."

KYMOGRAPHY

Kymography is a method by which the rhythmical movement of structures or organs can be graphically recorded on an x-ray film. It was originally designed for recording the contractions of the various chambers of the heart, and in this field it finds its greatest usefulness, although it is sometimes used to determine the presence or absence of pulsation in structures suspected of being aneurysms or other pathological conditions.

The kymograph consists of a large lead plate in which parallel transverse slits 0.4 mm. in width have been cut across the entire width of the sheet at 11 mm. intervals. A suitable mechanism moves the film across the long axis of the slits for a distance equivalent to the space between the slits. This arrangement provides graphic records of numerous locations in the organ under examination and does not therefore require accurate centering to any particular location as was true of the older type of single slit kymographs.

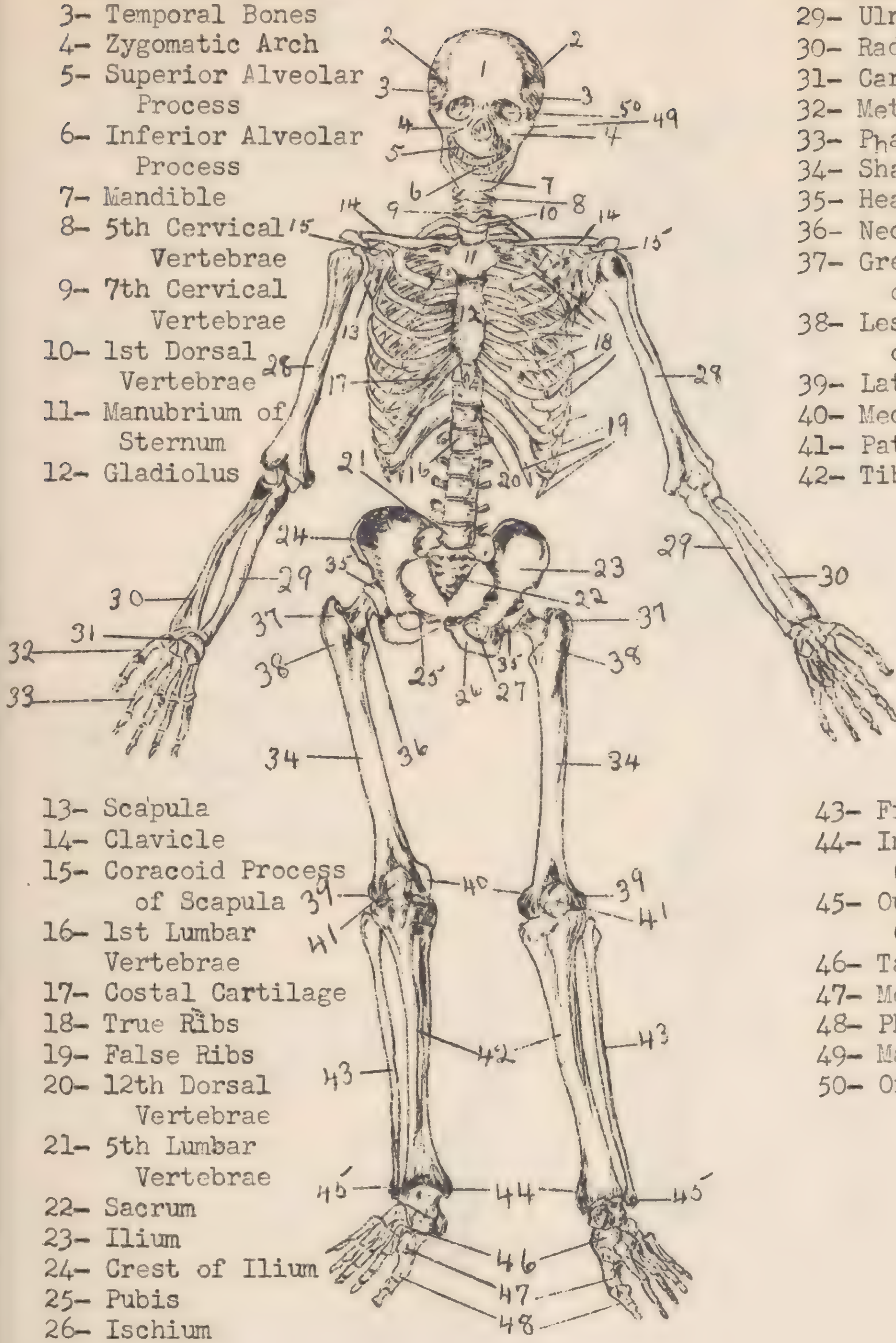
X-RAY TECHNICIANS HANDBOOK

ANATOMY AND VOCABULARY SECTION

SPECIAL SERVICE SCHOOL

LETTERMAN GENERAL HOSPITAL

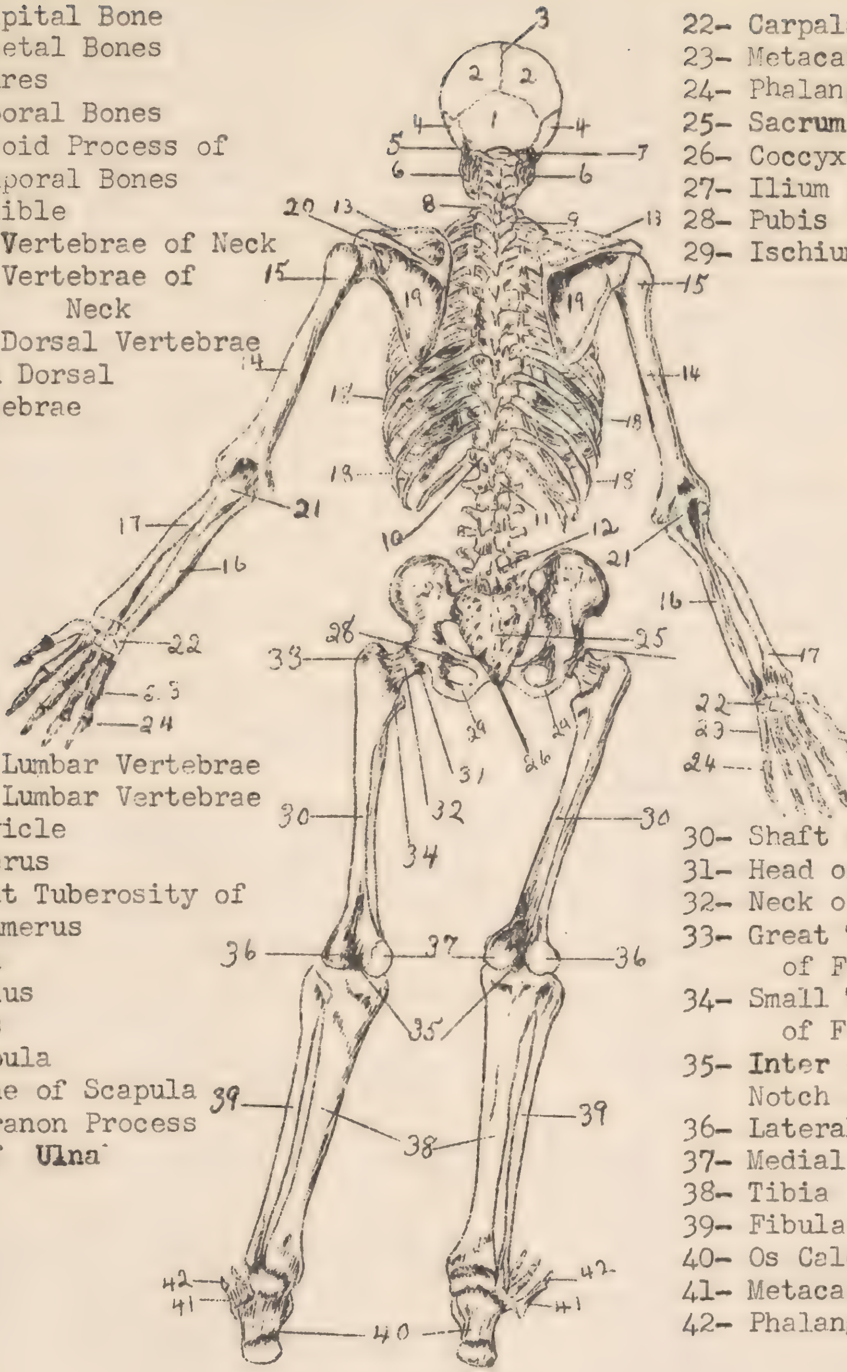
1– Frontal Bone
2– Parietal Bones
3– Temporal Bones
4– Zygomatic Arch
5– Superior Alveolar Process
6– Inferior Alveolar Process
7– Mandible
8– 5th Cervical Vertebrae
9– 7th Cervical Vertebrae
10– 1st Dorsal Vertebrae
11– Manubrium of Sternum
12– Gladiolus



13– Scapula
14– Clavicle
15– Coracoid Process of Scapula
16– 1st Lumbar Vertebrae
17– Costal Cartilage
18– True Ribs
19– False Ribs
20– 12th Dorsal Vertebrae
21– 5th Lumbar Vertebrae
22– Sacrum
23– Ilium
24– Crest of Ilium
25– Pubis
26– Ischium

27– Obturator Foramen
28– Humerus
29– Ulna
30– Radius
31– Carpals
32– Metacarpals
33– Phalanges
34– Shaft of Femur
35– Head of Femur
36– Neck of Femur
37– Great Trochanter of Femur
38– Lesser Trochanter of Femur
39– Lateral Condyle
40– Medial Condyle
41– Patella
42– Tibia

43– Fibula
44– Inner Malleolus (of the Tibia)
45– Outer Malleolus (of the Fibula)
46– Tarsals
47– Metatarsals
48– Phalanges
49– Maxilla
50– Orbit



1- Occipital Bone
2- Parietal Bones
3- Sutures
4- Temporal Bones
5- Mastoid Process of Temporal Bones
6- Mandible
7- 1st Vertebrae of Neck
8- 7th Vertebrae of Neck
9- 1st Dorsal Vertebrae
10- 12th Dorsal Vertebrae
11- 1st Lumbar Vertebrae
12- 5th Lumbar Vertebrae
13- Clavicle
14- Humerus
15- Great Tuberosity of Humerus
16- Ulna
17- Radius
18- Ribs
19- Scapula
20- Spine of Scapula
21-Olecranon Process of **Ulna**

22- Carpals
23- Metacarpals
24- Phalanges
25- **Sacrum**
26- Coccyx
27- Ilium } Innominate
28- Pubis } or
29- Ischium } Hip Bones
30- Shaft of Femur
31- Head of Femu
32- Neck of Femur
33- Great Trochanta of Femur
34- Small Trochanta of Femur
35- **Inter** Condylar Notch of Femur
36- Lateral Condyle
37- Medial Condyle
38- Tibia
39- Fibula
40- Os Calcis
41- Metacarpals
42- Phalanges

I.

Anatomical: Introduction--Anatomical Terms: A thorough knowledge of anatomy, or that portion of anatomy concerned with the framework of the body, is essential to any X-ray technician. It will be the foundation of orders in which the Physician makes known to the technician the part to be X-rayed. A knowledge of the bone structure is then necessary in order that the technician may properly position the patient in order to obtain radiographs which will either confirm or deny the presence of pathology in the part indicated by the Physician. As an introduction to this study of the bones of the body, called Osteology, the following terms of anatomical "direction" or "position" are given:

1. Anterior - refers to the region of the body which is forward in normal progression; or toward the front.

2. Posterior - the opposite of anterior; or toward the back of the body.

3. Medial - means near the midline. (A line drawn down the front side of the body so as to divide the body in two equal parts.)

4. Lateral - the opposite of medial; or away from the midline.

5. Proximal - means nearer to the source or point of attachment. Example: The proximal end of the forearm is at the elbow.

6. Distal - the opposite of proximal; the distal end of the forearm is the wristend.

7. Prone - the body is in a horizontal position with the face down.

8. Supine - the body is in a horizontal position with the face up.

9. Flexion - the bending of, or angulation of a joint in the direction of its normal movement. The elbow must be flexed in order for the hand to reach the mouth.

10. Extension - a movement to straighten a part; as in the arm. To move the hand from the mouth until the elbow is straight is to completely extend the forearm.

11. Abduction - movement of an extremity away from the body, sideward--movement away from the median plane.

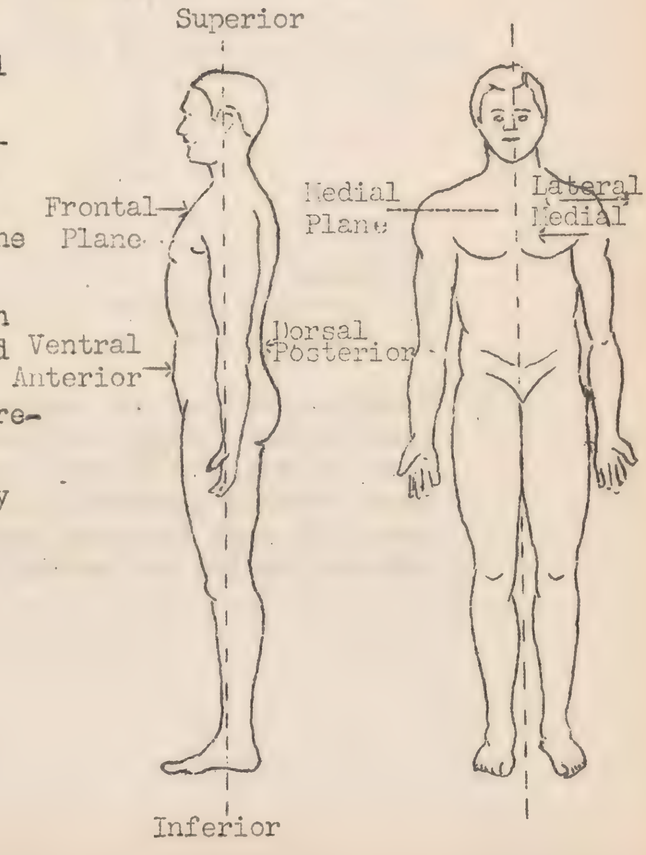
12. Adduction - movement toward the median plane. If the hand is raised sideward to the level of the shoulder (abduction) then adduction would lower the hand back to the side of the body.

13. Internal Rotation - rotation of a part toward the medial plane. If the leg is rotated so that the toes of the foot point toward the left side, the movement has been Internal Rotation.

14. External Rotation - the opposite of internal rotation.

15. Ventral - the front side of the body. (Anterior)

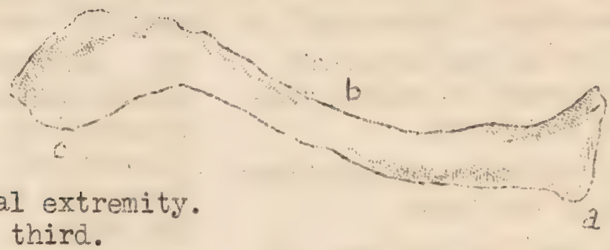
16. Dorsal - the back side of the body. (Posterior)



II. ANATOMICAL (1)

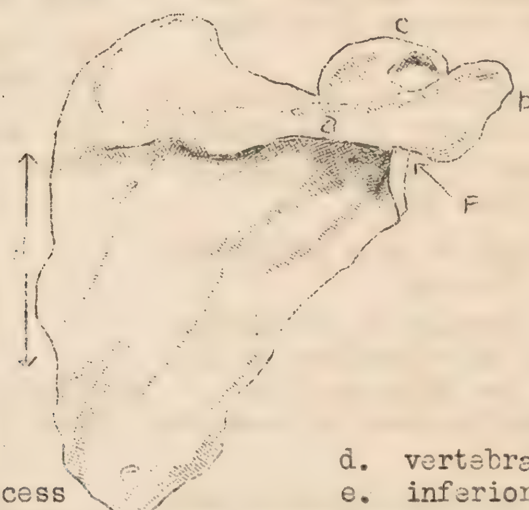
Bones of Upper Extremity

1. Clavicle: Commonly called the collar bone. It is an elongated, slender bone, lying at the root of the neck, above the first rib. It extends from the upper end of the sternum (breast bone) to the acromion process of the scapula.



a. Proximal extremity.
b. Middle third.
c. Distal extremity.

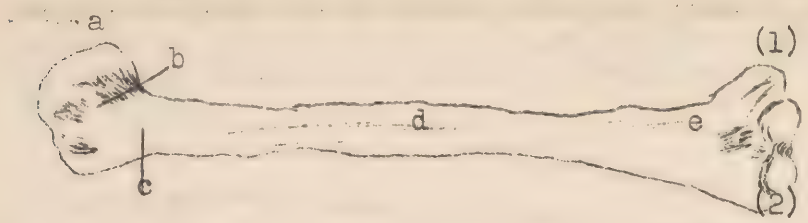
2. Scapula: Commonly called the shoulder blade. It has no bony attachment to the vertebral column; it is free to move with only the muscles holding it in place. The scapula extends from the 2nd to the 7th rib on the back.



a. spine
b. acromion process
c. coracoid process
d. vertebral border
e. inferior angle
f. glenoid cavity

3. Humerus: Bone of the upper arm. The proximal end displays a head, which fits into the glenoid cavity, a neck, a greater tubercle, and a lesser tubercle. The shaft extends downward from the neck to a widened distal extremity with two bony projections, one on the medial side and called the medial epicondyle; the other on the

lateral side and called the later epicondyle.



a. head

b. anatomical neck

c. surgical neck

d. shaft

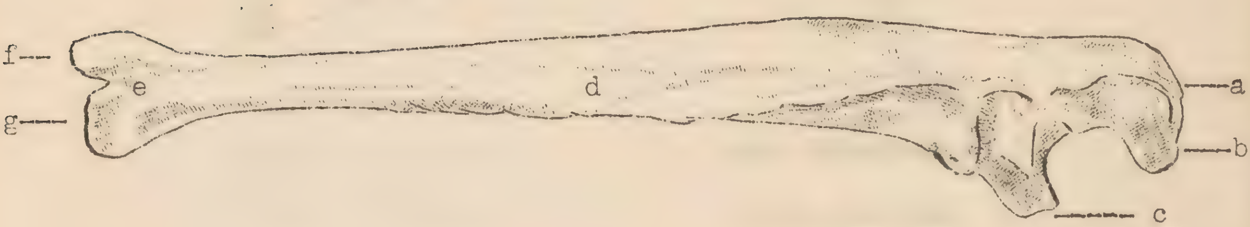
e. distal extremity
   (1) medial epicondyle
   (2) lateral epicondyle

4. Radius: The lateral bone of the forearm. The proximal end has a head which articulates with the humerus and also with the ulna. (the other and medial bone of the forearm) The neck, a slightly constricted portion, separates the head from the shaft. The distal end articulates with the lunate and navicular bones of the wrist, and with the ulna. It is chiefly the movement of the radius that makes possible the pronation and supination of the forearm.

a. head
b. neck
c. shaft
d. distal extremity
e. styloid process

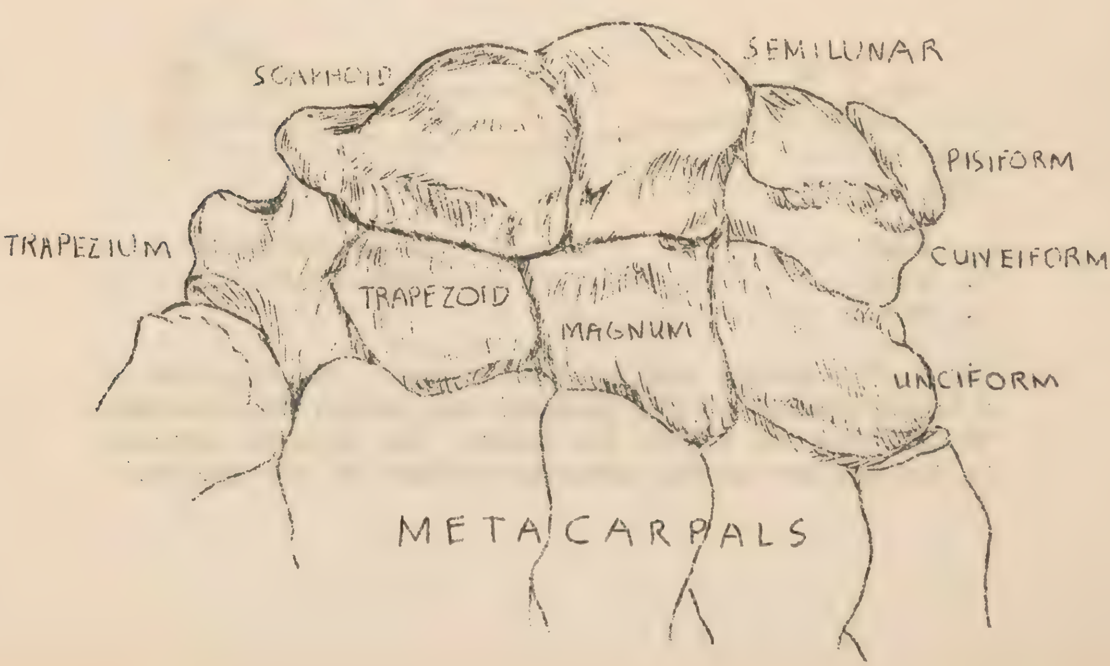
5. Ulna: The medial bone of the forearm. The ulna has a large process on the proximal end called the olecranon, which forms the tip of the elbow. The coronoid process is the process on the anterior surface of the same end

and the circular notch between these two processes is the articulating surface for the humerus. The distal end consists of a rounded portion called the head and a small projection known as the styloid process.

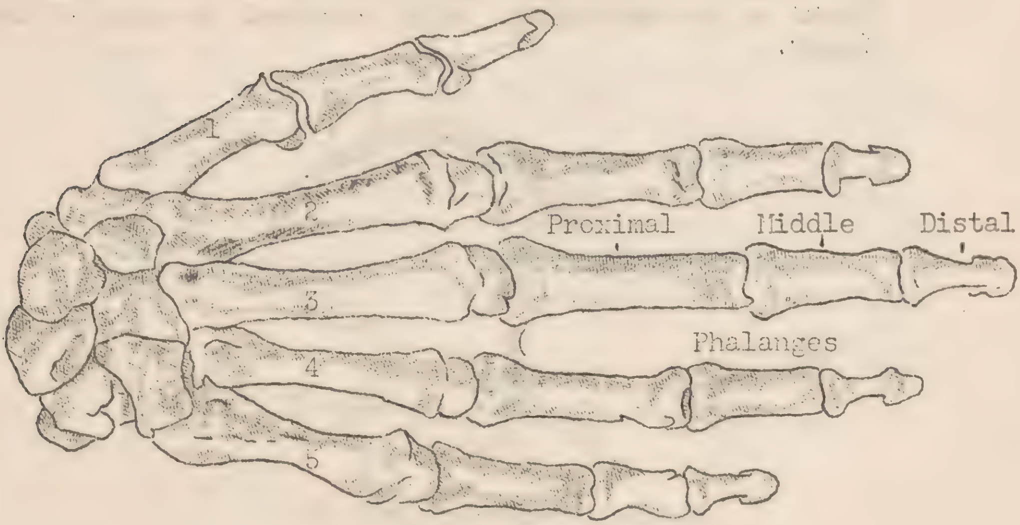


a. proximal end
b. olecranon process
c. coronoid process
d. shaft
e. head
f. styloid process
g. distal end

6. Carpal bones: These eight bones are the bones of the wrist. The proximal row contains from the lateral to the medial side: the navicular, lunate, cuneiform, and the pisiform bones. The distal row contains from the lateral to the medial side: the trapezium, trapezoid, capitate and hamate bones.



7. Metacarpal bones: Five bones forming the hand proper. They form the skeleton of the palm. The metacarpal bones articulate proximally with the bones of the wrist, and distally with the first row of phalanges (fingers) and with each other. They are numbered from the lateral to the medial side thus making the metacarpal of the thumb number 1.



8. Phalanges: The digits contain fourteen phalanges; these are shown above. Two in the thumb and three in each finger. The three rows are known as the proximal, middle, and distal phalanx.

III. Anatomical (1)

Bones of the Lower Extremity

1. Os Coxae: (Innominate bone) forms the pelvic girdle in an adult.

   It is comprised of three sections, the ilium, ischium, and pubis. The ilium is the broad, expanded upper portion of the pelvis; it forms the prominence of the hip. The ischium is the thick, inferior, posterior part of the os coxae which bears the weight in sitting. The pubis forms the front wall of the pelvis. It has a flat body, which meets its fellow at the symphysis. The rounded cavity near the center of the three sections is the acetabulum, which received the head of the femur.

a. ilium
b. ischium
c. pubis
d. iliac crest
e. anterior spine (superior)
f. acetabulum

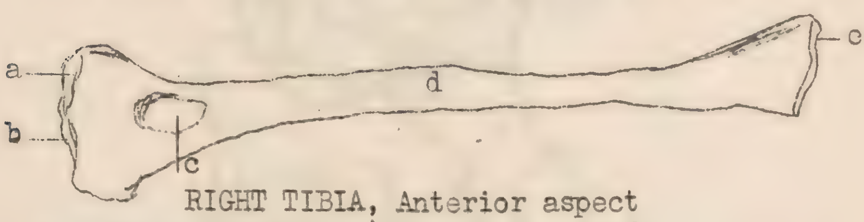
2. Femur: The femur, or thigh bone, is the longest bone in the body. The proximal end shows a head, which articulates with the acetabulum, a neck, a greater and a lesser trochanter. The distal end of the femur presents two condyles, separated posteriorly by the intercondyloid fossa. These condyles articulate with the head of the tibia. They are classed as medial condyle and lateral condyle.

a. head
b. neck
c. greater trochanter
d. lesser trochanter
e. shaft
f. medial condyle
g. lateral condyle

3. Patella: The patella, or knee cap, lies anterior to the knee joint, embedded in the tendon of the quadriceps femoris muscle. It articulates with the femur.

PATELLA, Anterior view.

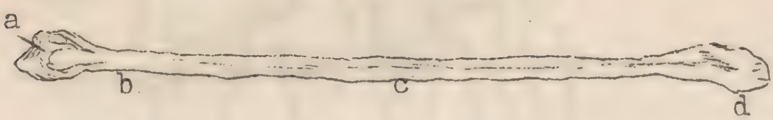
4. Tibia: The tibia, or shin bone, lies on the medial side of the lower leg. The proximal end shows condyles, medial and lateral, which articulate with the femur. The tuberosity is a prominence on the anterior surface of the proximal end. The distal end has a projection on the medial side, called the medial malleolus. The tibia unites distally with the talus (bone of the ankle joint) and the fibula.



RIGHT TIBIA, Anterior aspect

a. medial condyle
b. lateral condyle
c. tuberosity
d. shaft
e. medial malleolus

5. Fibula: The fibula, or calf bone, lies on the lateral side of the lower leg. The proximal end is called the head, it articulates with the tibia. The part of the shaft immediately adjoining the head is called the neck of the fibula. The distal end forms the lateral malleolus, and articulates with the talus and the tibia.



RIGHT FIBULA, Anterior aspect

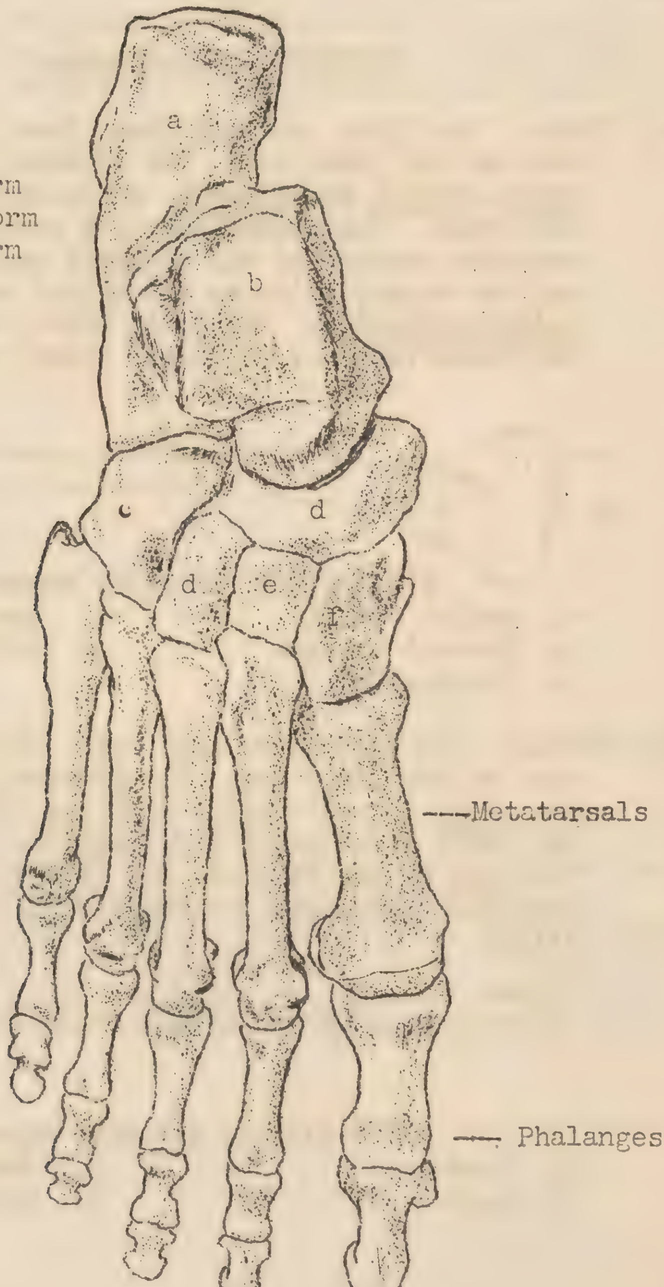
a. head
b. neck
c. shaft
d. lateral malleolus

6. Tarsal Bones; Seven in number, calcaneus (heel bone), talus, cuboid, navicular, and first, second and third cuneiform.

7. Metatarsal bones: Five in number. Articulate proximally with the tarsal bones, and distally with the first row of the Phalanges. See drawing.

8. Phalanges: There are two phalanges in the great toe, and three in each of the other toes.

a. Calcaneus
b. Talus
c. Cuboid
d. Navicular
e. First cuneiform
f. Second cuneiform
g. Third cuneiform

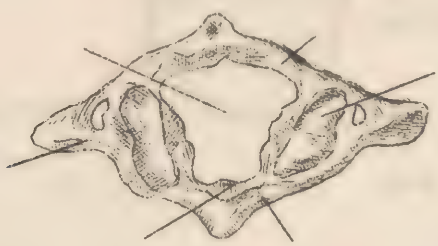


The bones of the trunk include the thirty three vertebrae, the sternum, and the twenty-four ribs.

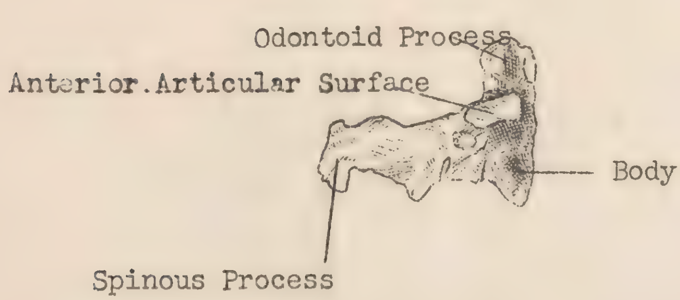
Vertebrae

The vertebral column is composed of seven cervical, twelve thoracic (of dorsal), five lumbar, the sacrum and the coccyx. Each vertebrae (except the first two cervical) consists of a body and an arch. The arch is formed by the pedicles and the laminae, which enclose the vertebral foramen. Seven processes are found on each vertebrae; these are four articular, which serve to connect the body with that above and with that below, two transverse, at the junction of the pedicles and laminae, and one spinous, which projects from the junction of the laminae.

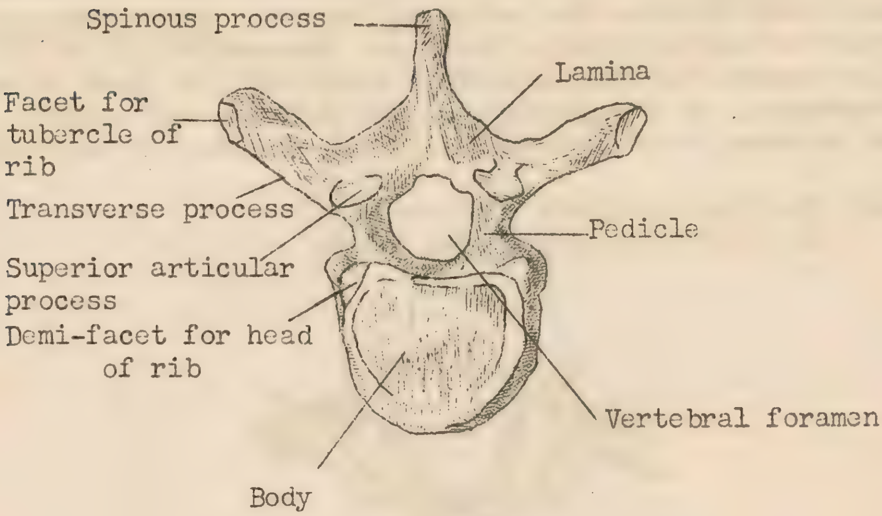
1. The first cervical vertebrae is a bony ring called the Atlas.



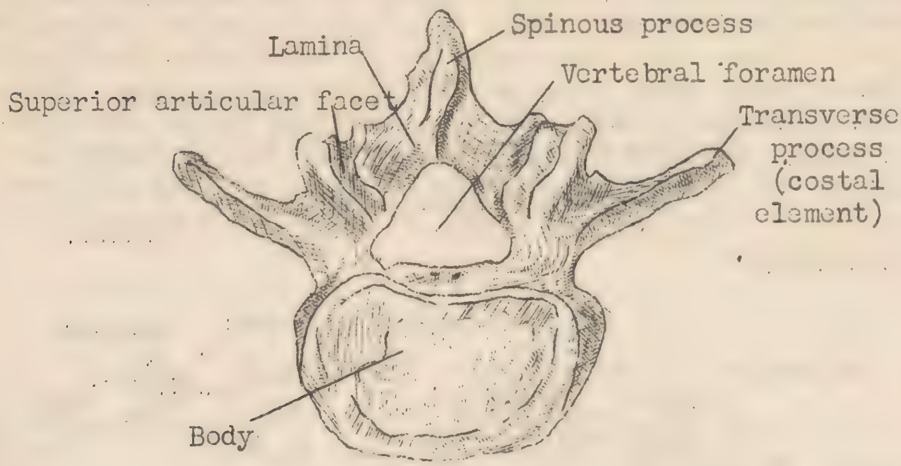
2. The second cervical vertebrae is called the Axis; it posses an odontoid process, about which the atlas rotates.



3. The twelve thoracic vertebrae, in addition to being larger and stronger than the cervical, show articular facets for the heads and tubercles of the ribs, with the exception of the last two, which show no surfaces for the tubercles of the ribs. Each rib attaches by its head to two vertebrae and by its tubercles to the transverse process of the vertebra to which it corresponds.

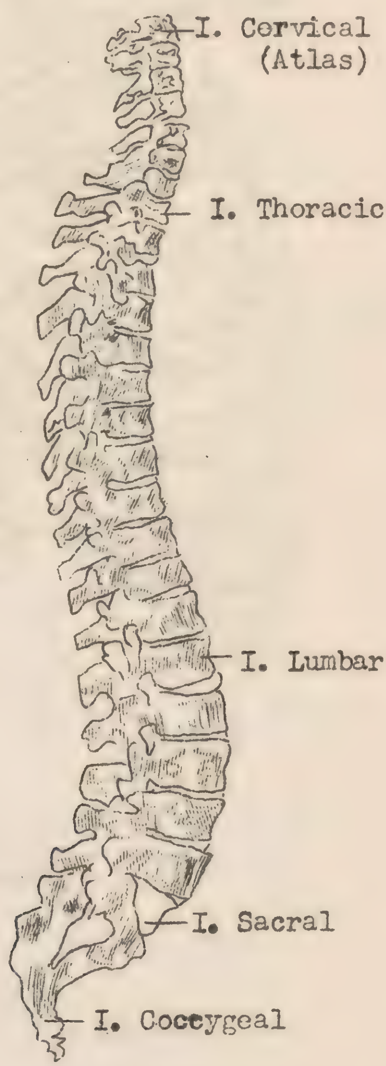


4. The five lumbar vertebrae are the largest of all. The body is broad; the vertebral foramen is three-sided. The pedicles are short and diverge only slightly. The laminae are broad at the sides; the spinous process is a flat projection. The articular processes are large.



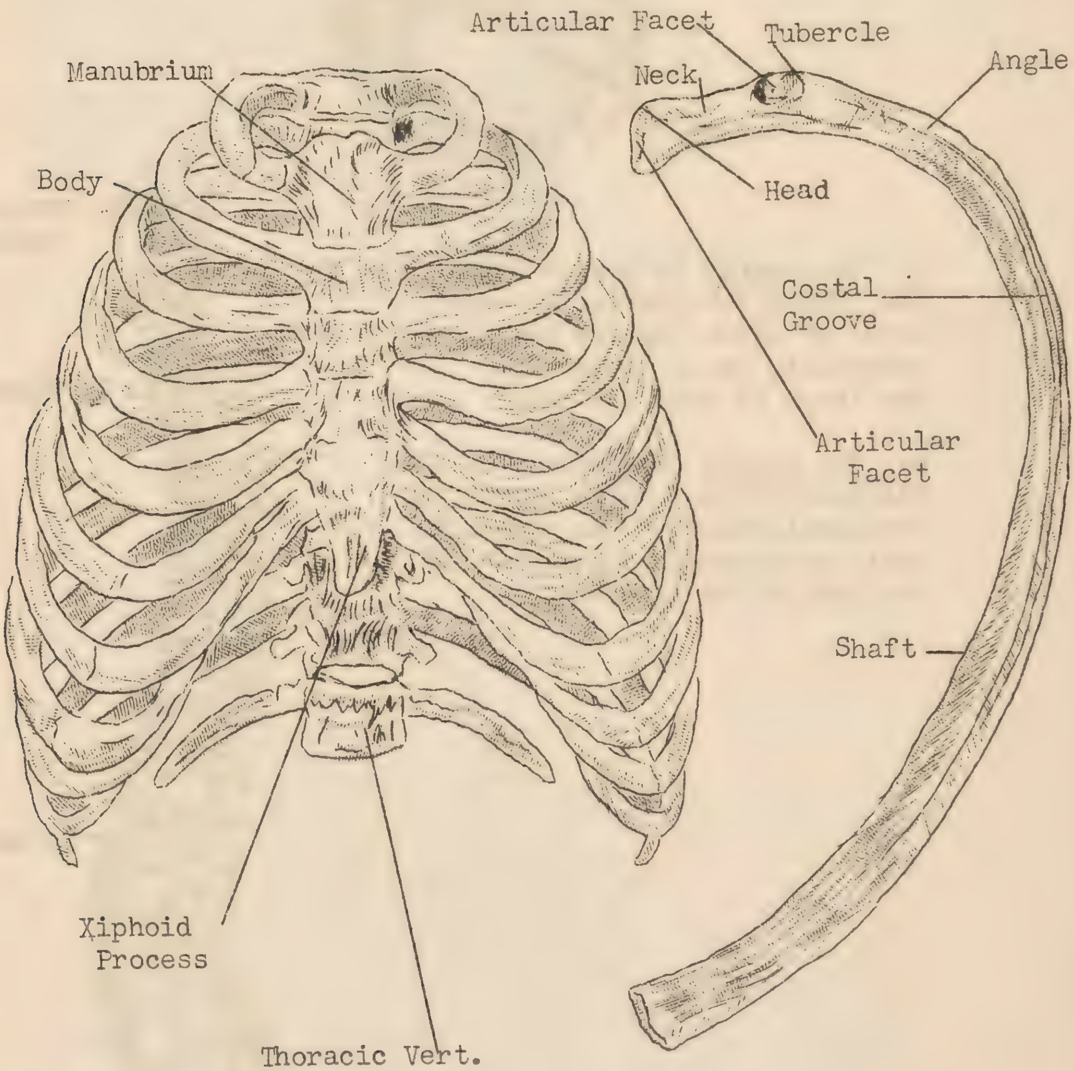
5. The sacrum is composed of five fused vertebrae; the upper three of which support the innominate bones laterally. The lower is bent forward.

6. The coccyx is composed of four flattened plates which represent vertebral bodies. The proximal plate or segment is attached to the apex of the sacrum.



7. The sternum is made up of three portions; these are the manubrium, body (gladiolus) and xiphoid process.

8. There are twelve pair of ribs. They are attached to the thoracic vertebrae. The first seven pairs are attached to the sternum by means of the costal cartilages, and are called true ribs. The last five pairs are called false ribs. The false ribs are of two kinds; the first three pairs (8th, 9th, and 10th) have a cartilage attachment anteriorly only with the cartilage of the rib above itself. The 11th and 12th pairs have no attachment in front and are called floating ribs. A typical rib consists of a head, neck, shaft or body, and a sternal extremity.



There are eight bones forming the cranial vault. 1 occipital, 2 parietal, 1 frontal, 2 temporal, 1 ethmoid, and 1 sphenoid.

1. The occipital bone forms the posterior floor and wall of the vault. By this bone the cranium is supported upon the vertebral column.

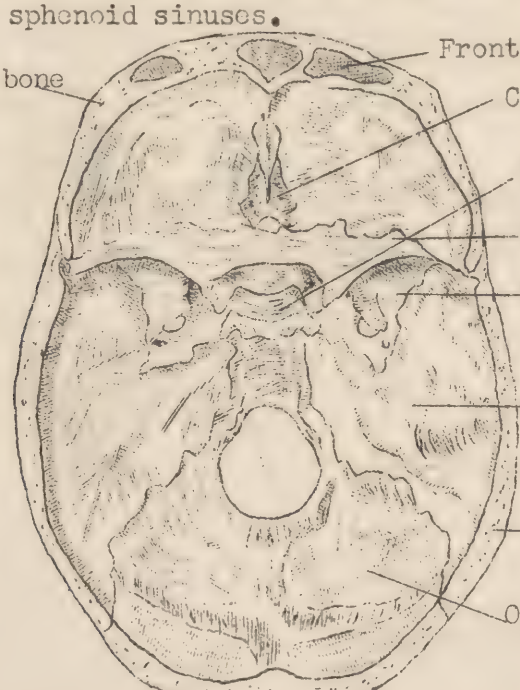
2. The parietals comprise the central portions of the lateral walls and roof of the cranium. They articulate anteriorly with the frontal bone, posteriorly with the occipital, above with each other, and below with the temporal bones.

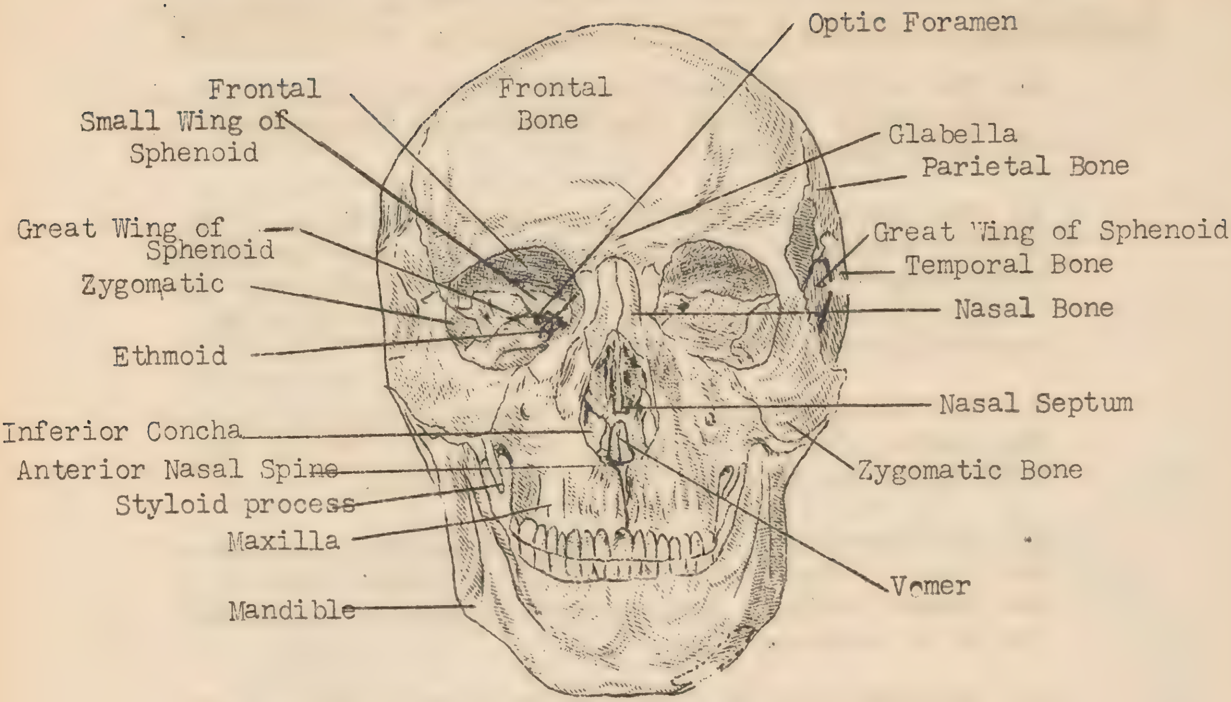
3. The frontal bone forms the anterior wall and roof of the vault. It also forms the roof of the orbits and a portion of the anterior floor of the skull.

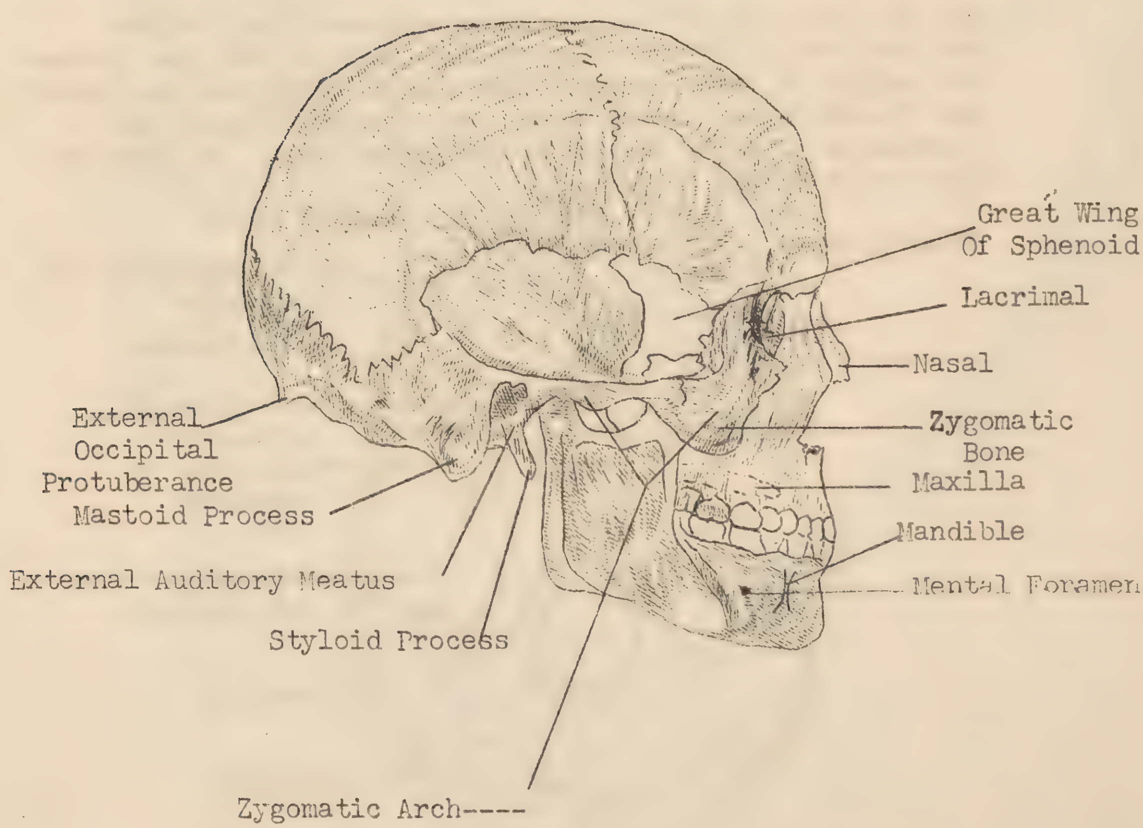
4. The temporal bones form the mid-lateral portions of the floor of the vault as well as the lower portion of the lateral walls. These bones contain the mechanical organs of hearing.

5. The ethmoid lies in the midline of the floor just anterior to the sphenoid and in contact with it and is joined laterally with the frontal bone. It contains the ethmoid sinuses.

6. The sphenoid is a somewhat bat-shaped bone forming the mid portion of the floor of the cranium and lies between the occipital and temporal bones posteriorly, and the ethmoid and frontal bones anteriorly. It contains a sadle like depression in which the pituitary gland lies. It contains also the sphenoid sinuses.




Optic Foramen
Frontal
Frontal Bone
Small Wing of Sphenoid
Glabella
Parietal Bone
Great Wing of Sphenoid
Great Wing of Sphenoid
Temporal Bone
Zygomatic
Nasal Bone
Ethmoid
Nasal Septum
Inferior Concha
Anterior Nasal Spine
Zygomatic Bone
Styloid process
Maxilla
Vomer
Mandible


Great Wing Of Sphenoid
Lacrimal
Nasal
External Occipital Protuberance
Zygomatic Bone
Maxilla
Mastoid Process
Mandible
External Auditory Meatus
Mental Foramen
Styloid Process
Zygomatic Arch----

There are fourteen bones making up the face. 2 maxillae, 1 mandible, 2 xygomatic. 2 lacrimal, 2 nasal, 1 vomer, 2 inferior nasal conchae, and 2 palate bones.

1. The fusion of the right and left maxillae forms the upper jaw. These bones contain the maxillary sinuses. They articulate laterally with the zygomatic bones.

2. The mandible is the bone of the lower jaw. It hinges on the temporal bones.

3. The zygomatic bones form arch connections between the temporal bones of the cranium and the maxillae. These form the prominences known as the cheek bones.

4. These bones form a small portion of the medial walls of the orbits at about the level of the base of the nose. They contain an opening for the lachrimal duct.

5. The two nasal bones form the bridge of the nose.

6. The vomer is a thin bone, somewhat quadrilateral in shape, forming the posterior and lower part of the nasal septum.

7. The inferior nasal concha extends horizontally along the lateral wall of the nasal cavity and consists of a lamina of spongey bone, curled upon itself like a scroll.

8. The palatine bones are located at the back part of the nasal cavity between the maxilla and the sphenoid bones. It also helps to form three cavities; the roof of the mouth, the floor and lateral wall of the nasal cavity, and the floor of the orbits.

Dentistry has three distinct aspects: the prevention of dental disease; the elimination of focal infection; and the restoration of missing or brokendown teeth and associated parts. In each type of dental service the radiodontic examination has specific functions which cannot be fulfilled by an other method of study.

Because radiographs accurately record the condition of the hidden portions of the dental areas, radiodontics is generally accepted by the dentist and patient alike as being the most effective method of augmenting the clinical examination. The value of the individual radiograph, however, is governed by the amount of diagnostic detail that is recorded. Therefore, it is very important that the technician be familiar not only with the x-ray techniques themselves but also with the anatomy of the mouth so that these techniques can be best adopted to fit the conditions under which he must work to get good diagnostic results.

The teeth are arranged in the alveolar processes of the jaws. There are eight teeth in each half of each jaw. From the center in front, backward, these are named the central and lateral incisor teeth, the canine or cuspid tooth, the first and second premolar or bicuspid teeth, and the first, second, and third molar teeth. Each tooth has a crown which projects above the gum, a neck which is surrounded by the gum margin, and one or more roots extending into the bone of the jaw.

The Army system of numbering teeth is from the median line. It is an imaginary line drawn through the body dividing it into right and left halves. The teeth are numbered from one to eight on each side of this line in the upper jaw, and from nine to sixteen in the lower.

That part of the tooth which is toward the midline of the teeth is called the mesial surface, and that away from the midline is called the distal surface. The surface toward or in contact with the cheek is known as the buccal surface, and that toward the tongue or palate is the lingual or palatal surface. The space between two adjoining teeth is known as the proxiaml space, the surfaces being known as the proximal surfaces.

Army system of numbering:

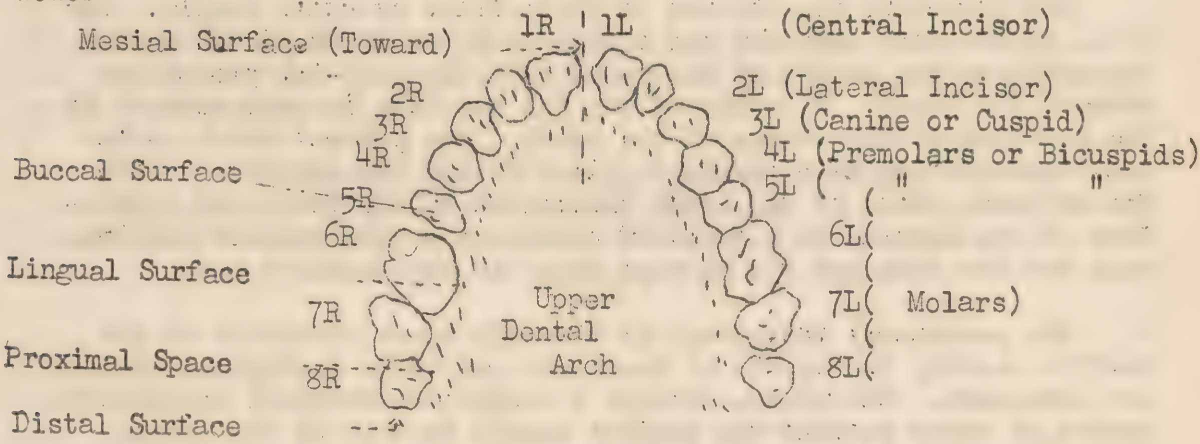
Upper | Median Line

Right (R) | Left (L)

8 7 6 5 4 3 2 1 | 1 2 3 4 5 6 7 8

16-15-14-13-12-11-10-9-9-10-11-12-13-14-15-16-

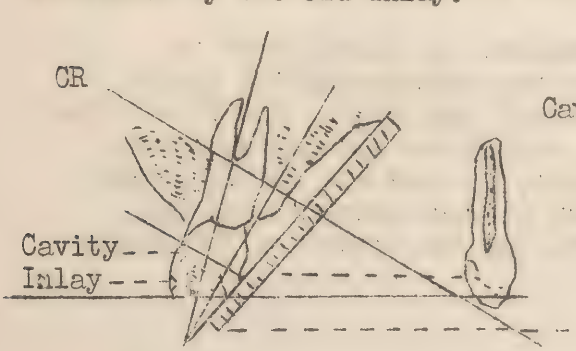
Lower

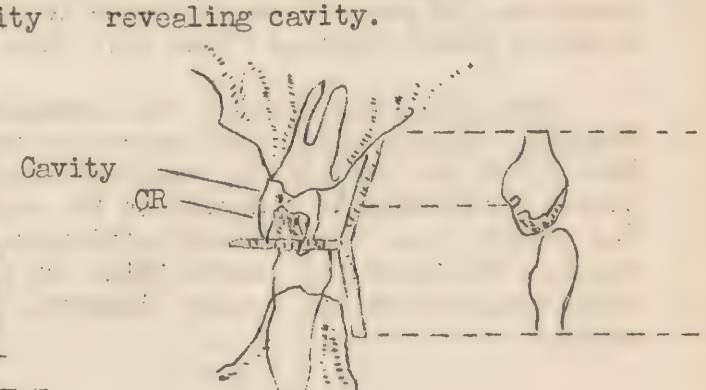


The two main types of examination of the teeth are the bite-wing and the periapical. Each performs a distinct service which cannot be satisfactorily supplemented by the other. The bite-wing examination is made with a special form of dental film. These films are used in the search for dental decay, for degenerative changes in the pulp, and for the conditions of the bone margin around the necks of the teeth. On these films the images of the crowns and necks of the teeth are projected without the distortion present on the usual dental roentgenograms. Because of the low angle of projection and the vertical position of the film packet, the x-rays are permitted to pass straight through the enamel ridge and the gingival portion of the crown. This examination reveals areas that are obscured in the periapical radiograph because of the high angle from which the rays are projected in making it. The figure below shows how cavities are hidden by intervening objects in the periapical method, but are plainly visible in the bite-wing study.

Angle of projection of central ray (CR) for periapical examination is so great that the cavity is hidden by the old inlay.

Angle of projection is less in the bite-wing examination revealing cavity.





The bite-wing differs from the film used for periapical studies in size and shape and in that it has a projecting bite-tab on which the patient bites to hold the film in position. These films are produced in three adult sizes two of which are for the molar and premolar regions, the smallest size being used in the anterior part of the mouth.

The technique for the use of these films is quite simple. The film, of the size used for the region to be examined, is placed in the mouth on the inside of the teeth with the bite-tab projection between the teeth. By means of the tab the film is approximated to the surfaces of the crowns of the teeth. The patient bites on the tab, thus holding it securely in place during the exposure. With the occlusal plane of the teeth horizontal of the floor, an angulation of ten degrees in a downward direction is the correct inclination for the tube and the correct angle of the incident rays.

The periapical radiograph is the only means available to the dentist whereby the apices of the teeth and their contiguous tissues are disclosed. Therefore, without a complete periapical radiodontic record of every patient the dentist cannot be sure of the foundation upon which to base his treatment. The complete periapical examination gives the dentist a comprehensive record of the hidden areas in and about the apices of the teeth. Moreover, periapical radiographs of individual regions are of first importance in every phase of dental procedure in revealing the conditions to be treated, and serving as the basis for determining the best method to follow.

The standard size periapical film is $1\frac{1}{2}$ inches by 1 5/8 inches for the normal adult mouth. Smaller sizes can be obtained for children and adults with narrow dental arches. Each film is covered with a light-proof and moisture proof paper. The film also has a lead foil inserted in the back to protect it from secondary radiation that is naturally present in the oral cavity during the x-ray exposure, and which would cause fog.

In the periapical examination anywhere from eleven to eighteen films can be used in a complete examination of the average adult. Sixteen films is the technique most recommended as it allows for an amount of overlapping thus assuring that all teeth will be properly examined. If proper care is taken in placing the films in the patients mouth fourteen films will also make a good x-ray examination.

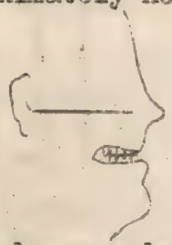
When using the sixteen film procedure the dental arch is divided, anatomically, into halves by the median-sagittal plane. Four films are used in the examination of each half. The first film placed vertically is centered on the medial and lateral incisors. The second film, also placed vertically, is centered on the cuspid tooth. The third and fourth films are placed horizontally, the third centered on the second bicuspid, and the fourth on the second molar.

The first essential in dental x-ray exposure procedure in the periapical examination is the establishment of the proper position of the patient's head, so that definite average projection angles may be used in every radiographic region, in every type of examination. If incorrect head positions are used, the images produced on the films will not be accurate or diagnostic.

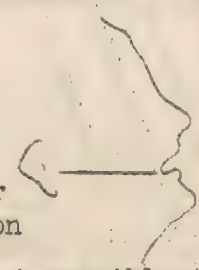
In the maxillary examination the head should be so positioned in the headrest that the occlusal place of the maxillary teeth is horizontal; a line from the tragus of the ear to the ala of the nose, which is used as a guid in positioning the head, will then be approximately horizontal.

For the mandibular examination the head should be lowered until the occlusal plane of the mandibular teeth is horizontal; a guide line from the tragus of the ear to the corner of the mouth will then be approximately horizontal.

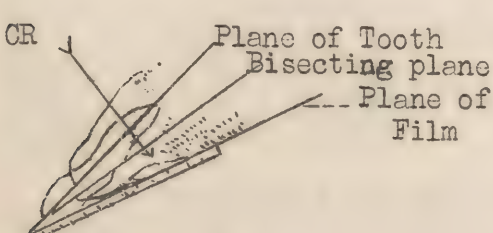
Maxillary
Examination



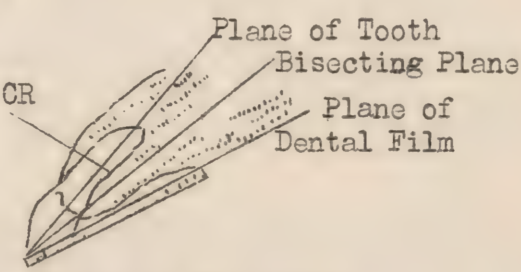
Mandibular
Examination



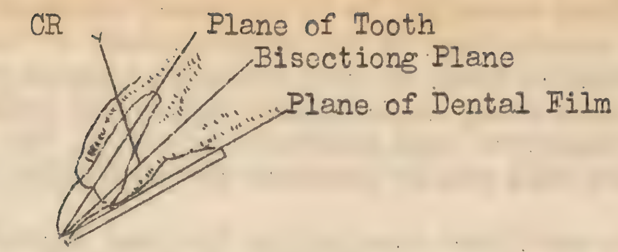
Except in the lower molar regions, it is impossible to place dental films parallel with the long axes of the teeth. The films must be placed against the soft tissues of the inside of the mouth and against the crowns of the teeth. In this position the roots of the teeth and the more deeply placed portions of the films will be separated by a considerable space, the plane of the films and the long axes of the teeth forming an angle. Because of this, in dental x-ray it is impossible to direct the rays perpendicularly to the teeth or to the films. They must be directed obliquely through the teeth, striking the films at an angle. This causes distortion of the images on the films. They rays must be directed in such a way that this distortion will be reduced to a minimum, the image appearing as nearly as possible the exact size and shape of the teeth. IN ORDER TO PRODUCE AN ACCURATE SHADOW IMAGE OF THE TEETH, THE CENTRAL RAY MUST BE DIRECTED PERPENDICULARY TO A PLANE DISECTING THE ANGLE FORMED BY THE LONG AXIS OF THE TEETH AND THE PLANE OF THE FILM PACKET.



Correct Projection
Normal Image

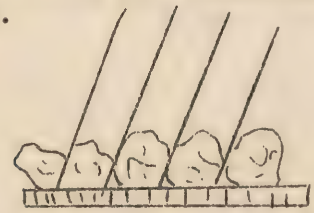


Incorrect Projection
Elongated Image

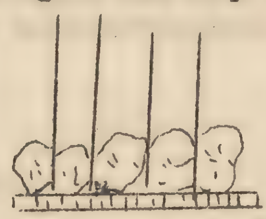


Incorrect Projection
Foreshortened Image

In addition to being projected from the correct vertical angle, the central ray must be directed from the correct horizontal angle in order to prevent overlapping of the images of the crowns of the teeth; the rays must pass straight through the interproximal spaces.



Incorrect Horizontal Projection



Correct Horizontal Projection

The technical essentials that must be observed in x-ray of the teeth may be grouped under four headings:

1. The position of the patients head.
2. The position of the films in relation to the teeth.
3. The position of the x-ray tube and the angle of the incident rays.
4. The selection of the proper exposure factors.

.Roentgenologic examination is of the utmost importance in detecting the presence and extent of disease with in the lungs and pleurae. To enumerate the conditions in which it is useful would be to make a list of the diseases of these structures in which there are macroscopic pathological changes.

Roentgenologic examination of the lungs should be both fluoroscopic and roentgenographic. Roentgenograms of the lungs are made to register on the films the shadows of the pathological processes so that they may be studied in detail, and as a permanent record for comparison with those of later examinations. While gross lesions in the lungs often can be identified with the fluoroscope, fluoroscopy should never be depended on in searching for early tuberculous infection nor for furnishing the details of any type of pathological process.

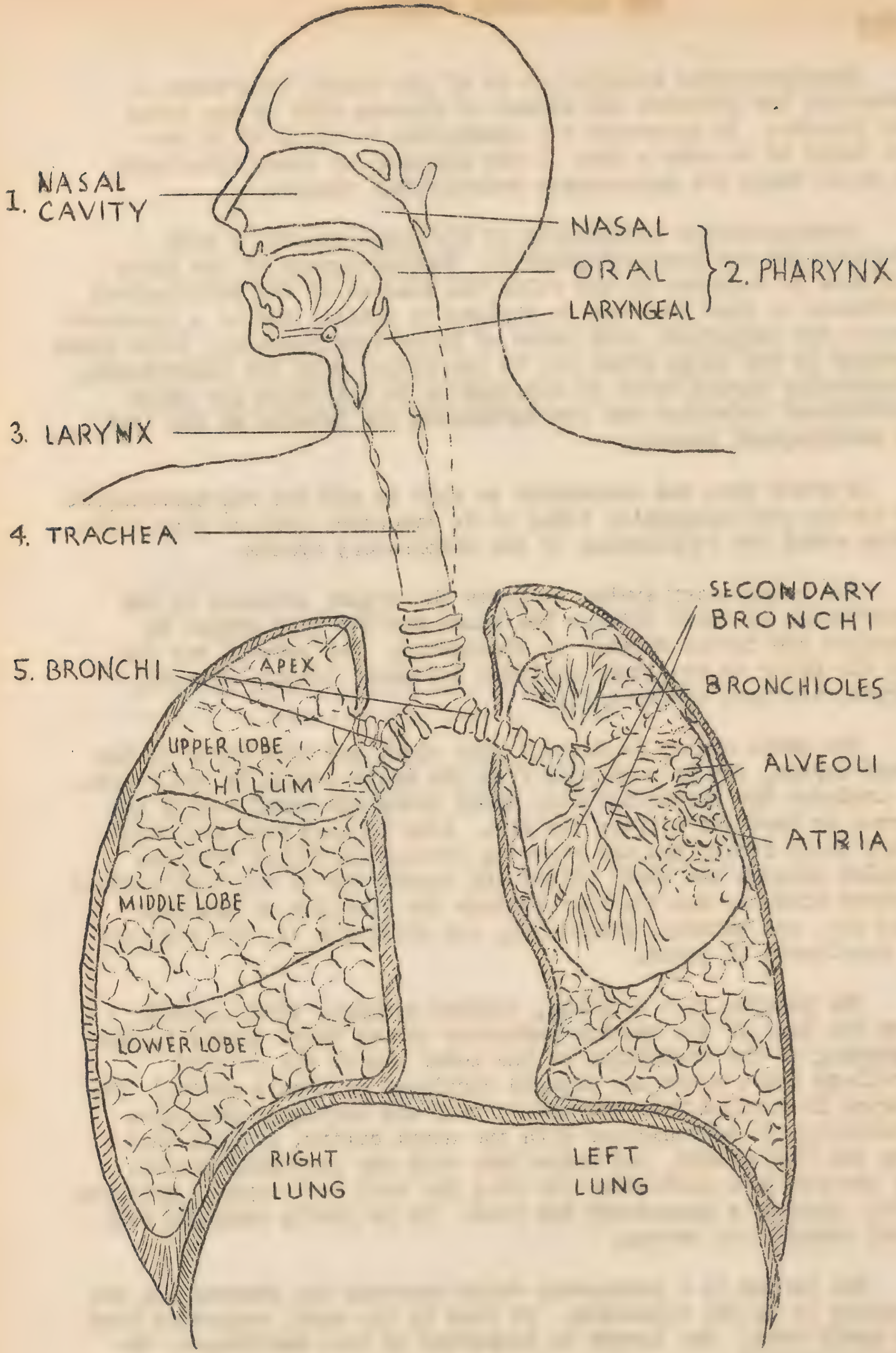
In order that the technician be able to aid the roentgenologist in taking good diagnostic films it is important that he know something about the functioning of the respiratory system.

The respiratory system includes the organs involved in the interchange of gases between the blood and the air; oxygen is absorbed and carbon dioxide is eliminated. The passage way for the air going to the lungs includes the nasal cavity, pharynx, larynx, trachea, and bronchi.

The nasal cavity is divided into right and left parts by the nasal septum, and is separated from the mouth cavity by the palate. It includes the mucoperiosteum, which lines the nasal cavity and serves to warm and moisten the air. Also located here are small hairs which strain the air removing foreign particles that are inhaled through the nose. Since the structures of the nose contain various tissues, and together perform the function of transferring air, and warming, moistening, and straining it, the nose may be considered an organ.

The pharynx is a vertical, tubular passage, which extends from the base of the cranium posterior to the nasal cavity to the beginning of the oesophagus at the lower end of the cricoid cartilage (just below the thyroid cartilage or Adam's apple.) The pharynx is divided into the nasal, oral and laryngeal portions. Anteriorly, it communicates with the nasal cavity, beneath this with the oral cavity, and below this with the laryngeal cavity. The pharynx is a passageway for air; the oral and larygeal portions serve, also as a passageway for food. It is richly supplied with blood vessels and nerves.

The larynx is a passageway which connects the pharynx and the trachea; it is the voice-box. It lies in the neck, suspended from the hyoid bone. The larynx is supported by nine cartilages; the three principal ones are the thyroid, cricoid, and epiglottis.


1. NASAL CAVITY
NASAL
ORAL
LARYNGEAL
2. PHARYNX
3. LARYNX
4. TRACHEA
SECONDARY BRONCHI
5. BRONCHI
APEX
BRONCHIOLES
UPPER LOBE
HILUM
ALVEOLI
ATRIA
MIDDLE LOBE
LOWER LOBE
RIGHT LUNG
LEFT LUNG

The epiglottis is shaped like a leaf and is located behind the root of the tongue and the body of the hyoid bone. A function of this cartilage is to prevent solid material taken in by the mouth from entering the trachea.

The trachea is a rigid tube, about eleven centimeters long, extending from the larynx to the bronchi. The trachea contains from sixteen to twenty C-shaped tracheal cartilages; these are not complete posteriorly. The cartilages serve to prevent collapse of the trachea. They are surrounded by dense connective tissue, which contains elastic fibers. Smooth muscle fibers are present in the posterior wall.

The trachea divides, at the level of the disc below the fourth thoracic vertebra, corresponding to the level of the junction of the manubrium and body of the sternum, into the two primary bronchi. Of these, the right bronchus is shorter and more nearly vertical than the left. (Foreign bodies which enter the trachea usually lodge in the right bronchus.) The primary bronchi divide at the root ofthe lung, and send a branch to each lobe of the lungs. The branches divide and subdivide into numerous secondary bronchi, which become smaller and smaller until they reach the bronchioles. The bronchioles divide into terminal bronchioles; these divide into atria. Each atrium communicates with several air sacs, into which the alveoli open. In the alveoli the changes of gases takes place. The capillaries in the walls of the alveoli connect branches from the pulmonary artery with tributaries to the pulmonary veins, While in these capillaries, the blood receives a new supply of oxygen, and gives up some of its carbon dioxide.

The lungs themselves are cone shaped organs which occupy the two lateral chambers of the thorascic cavity and are separated from each other by the structures contained in the mediastinum or middle space. This space is the median portion of the thorax and contains the heart in its pericardium, the large blood vessels connected with the heart, part of the thoracic duct, the thymus gland, the trachea, oesophagus, portions of the cagus and phrenic nerves.

Each lung has an outer surface which is convex, a base which is concave to fit over the convex protion of the diaphragm, and a summit or apex which rises about $\frac{1}{2}$ inch above the clavicle. The hilum is a vertical notch on the inner surface which gives passage to the bronchi, blood vessels, lymph vessels and nerves.

The right lung is composed of three lobes, the upper, middle and lower, and is larger, heavier and broader than the left, because of the heart inclining towards the left. It is also shorter by about one inch, because of the diaphragm rising higher on the right side to accomodate the liver.

The left lung is composed of two lobes, upper and lower, and is smaller narrower, and longer than the right. The front border is deeply notched to accomodate the heart.

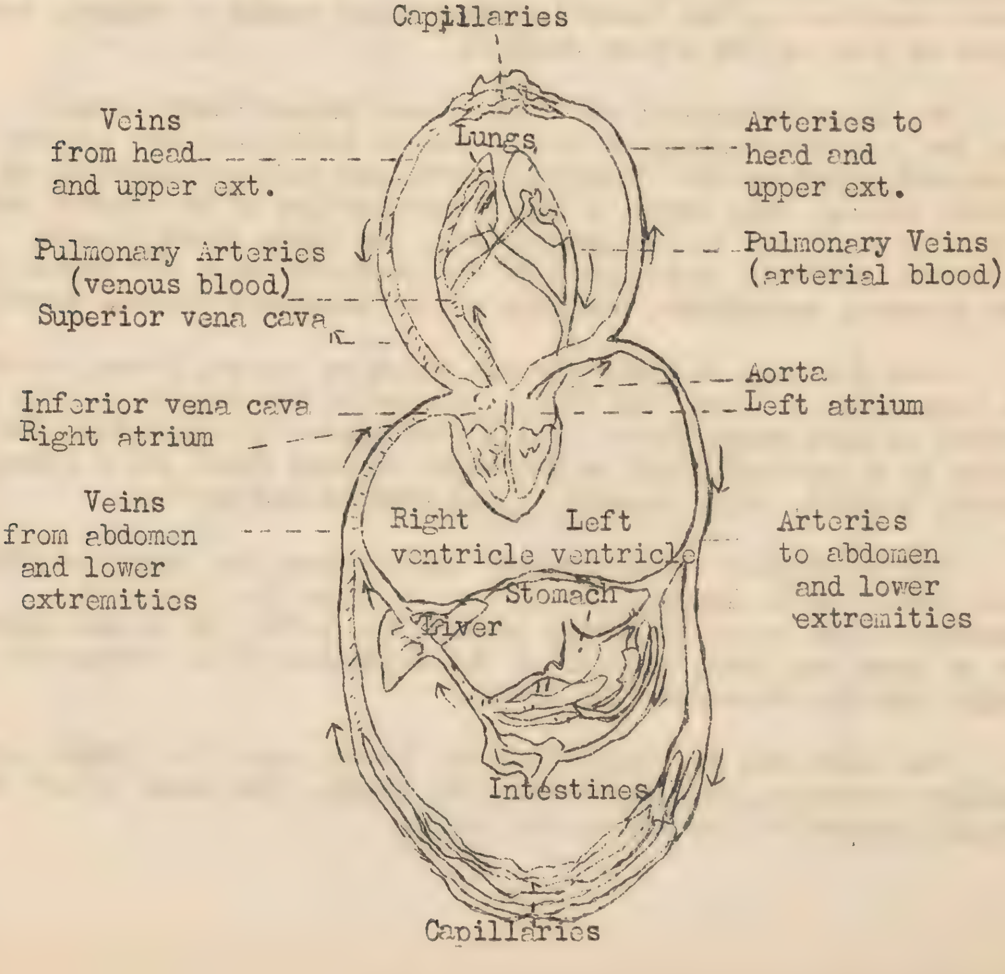
IX

Roentgenologic examinations of the Heart and aorta play an important part today in the diagnosis of many pathological conditions. By the use of fluoroscopy and roentgenography the size, shape, rate, rhythm, sequence of contractions of the auricles and ventricles, and movements on respiration can be determined.

Because of the skill that is required in being familiar with the normal and abnormal appearance of these structures this work is not undertaken alone by the average technician. However, it is important that the technician know something of the functioning of the heart and the blood vascular system so that under the guidance of a roentgenologist it is possible to carry out instructions that will result in good diagnostic films.

As in the case of examinations of the stomach and intestines it is advantageous to determine by fluoroscopy the location of the heart and aortic arch. The position used in fluoroscopy can then be used for the exposure of the films. By arranging the patient before a vertically placed film in the same position that he occupied behind the screen of the fluoroscope, similar images will be obtained. Since no particular position of the patient for roentgenograms of the heart and aorta will be correct in all instances this is a good procedure to follow.

The organs which compose the blood-vascular system are the heart, arteries, veins, and capillaries. The HEART is the contractile organ which forces the blood through the vessels. The ARTERIES carry blood away from the heart. The VEINS carry the blood toward the heart. The CAPILLARIES are the minute vessels which carry the blood from the arteries to the veins.

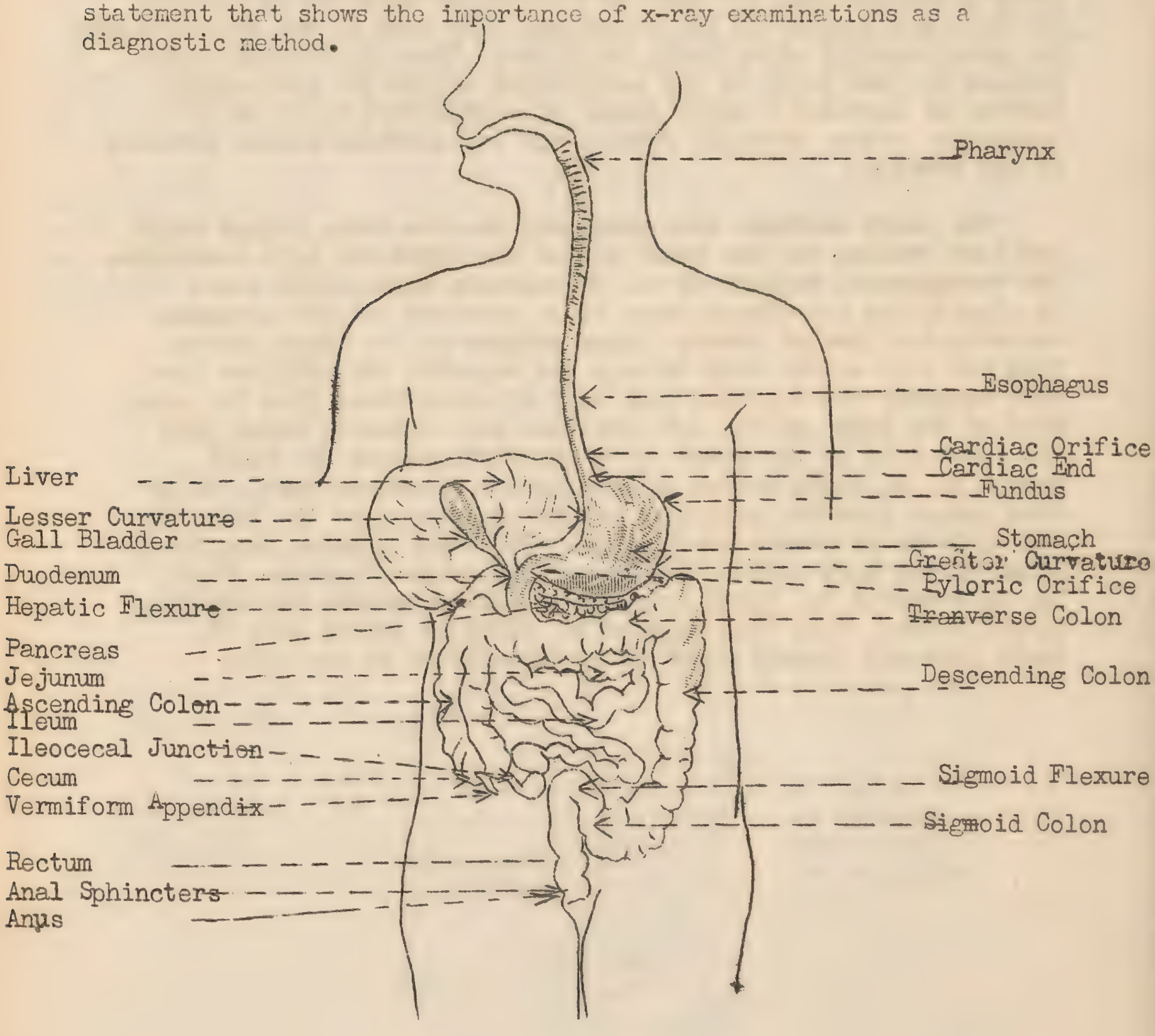


The HEART is a hollow muscular organ. It is somewhat conical in form; it averages twelve centimeters in length, eight to nine in width, and six in thickness. It weighs about three hundred grams in the male, and two hundred fifty in the female. The volume of the heart varies with the size of the individual. It is situated in the lower part of the thoracic cavity; the base faces upward and to the right; the apex faces downward and to the left; two thirds of the heart lies to the left of the median plane of the body, and one third to the right. Its normal position is about from the second to the sixth ribs. The heart is enclosed within a double-walled fibroserous sac, called the PERICARDIUM, which is composed of two parts. The inner part, the visceral pericardium, is closely adherent to the outer surface of the heart; the outer part, the parietal pericardium, forms a conical sac, the base of which rests upon and is attached to the upper surface of the diaphragm. The apex of the sac surrounds the great vessels which leave the heart. There is a slight space between the two parts of the pericardium called the pericardial cavity; it contains a small amount of pericardial fluid which serves to reduce friction between the two surfaces during movement of the heart.

The heart contains four chambers; the two above called right and left atrium, the two below called the right and left ventricle. The accompanying diagram of the circulatory system will serve to clarify the relation between these chambers and the incoming and outgoing flow of blood. Blood arrives at the right atrium from the rest of the body through the superior and inferior vena cava (veins); the superior vena cava bringing blood from the upper half of the body and the inferior vena cava bringing blood from the lower half of the body. From the right atrium the blood passes to the right ventricle through the tricuspid valve; it is then pumped into the pulmonary artery and passes to the lungs where the exchange of gasses takes place. The blood returns from the lungs to the left atrium by means of the pulmonary vein. From the left atrium the blood goes to the left ventricle through the mitral valve. From this chamber the blood is forced into the aorta (artery) through which it is distributed to the body.

X.

Roentgenologic examination is one of the few and by far the most useful of the direct methods of examining the gastrointestinal tract for evidences of disease. Since it is a method of visual study of images on the fluorescent screen or on films, it follows that most conditions which can be detected by it are macroscopic and of an organic nature. Those functional disturbances which produce abnormalities in the movements of the viscera themselves or of the contents through the stomach and intestines, or which, by spasm or otherwise, produce variations in outline or shape also often can be detected. It has been stated by competent authorities that in diseases of the alimentary tract the diagnosis of the average roentgenologist is correct in about 80 per cent of the cases, and that a skillful roentgenologist working under most favorable circumstances, is correct in from 90 to 95 per cent, a statement that shows the importance of x-ray examinations as a diagnostic method.



The gastrointestinal tract consists, briefly, of the oesophagus, stomach, and intestines.

The oesophagus is a comparatively straight tube about 9 inches long which commences at the lower end of the pharynx behind the trachea. It descends in front of the spine, passes through the diaphragm and terminates in the upper or cardiac end of the stomach. The oesophagus receives the food from the pharynx and, by a series of peristalic waves or contractions passes it on to the stomach.

The stomach is a thick-walled, pouch like bag, continuous with the oesophagus, lying immediately below the diaphragm, principally on the left side, the shape, size and position of the stomach are modified by changes within itself and in the surrounding organs. The stomach occupies variable positions with different individuals and also with the same individual, in the standing and reclining positions. In very heavy individuals the position of the stomach is usually much higher in the abdominal cavity than with thin individuals. The stomach usually occupies a position approximately three inches higher in the reclining position than it does in the upright position.

The stomach presents two openings and two borders or curvatures. The opening by which the oesophagus communicates with the stomach is called the cardiac orifice and that end of the stomach is known as the upper or cardiac end. The opening which communicates with the duodenum is called the pyloric orifice and this end of the stomach is called the pyloric end. The stomach normally curves toward the right side of the individual. The lesser curvature is along the inside or concave border from the cardiac to the pyloric end. The greater curvature is along the outside or convex border. The blind rounded end of the stomach to the left of the heart is called the fundus.

The stomach is connected by the pylorus to the small intestines. The small intestine is a tube approximately twenty feet long and fills the greater part of the abdominal cavity. Its diameter at the beginning is about two and one-half inches, gradually diminishing in size until it is hardly an inch in diameter at its lower end. The small intestine is divided into three portions, the duodenum, jejunum and the ileum.

The duodenum is approximately ten inches in length and is the shortest and broadest part of the small intestine. It extends from the pyloric end of the stomach to the jejunum. The point of junction of the duodenum with the pyloris is called the duodenal cap, because of its shape. The ducts from the pancreas and liver open into the duodenum.

The jejunum constitutes about two-fifths the remainder, or seven and one-half feet, of the small intestines and extends from the duodenum to the ileum.

The ileum constitutes the remainder of the small intestine and extends through many loops and coils from the jejunum to the large intestine, which it joins at a right angle. The junction of the small and large intestine is guarded by a sphincter muscle which acts as a valve and prevents the return of material that has been discharged into the large bowel. This is known as the ileocecal valve.

The large intestine is about five feet long and about two and one-half inches wide at its widest part. It extends from the ileum to the anus. It is divided into three parts; the cecum with the vermiform appendix, colon, and rectum.

The cecum is a large lined pouch at the beginning of the large intestine on the right side. The small intestine opens into the side wall of the large intestine about two and one-half inches above the commencement of the large intestine. This two- and one-half inches of large intestine forms a cul-de-sac below the opening and is called the cecum.

The vermiform appendix is a narrow, wormlike tube about the diameter of an ordinary lead pencil and from three inches to seven inches in length. It is attached to the lower end of the cecum, but its direction and location are very variable. In a general way it may be said to be located in the right iliac region.

The colon, through one continuous tube, is subdivided into the ascending, transverse, and descending colon, with the sigmoid flexure. The ascending portion ascends on the right side of the abdomen until it reaches the under surface of the liver, where it bends abruptly to the left and forms the hepatic flexure, and is continued left across the abdomen as the transverse colon until, reaching the left side, it curves beneath the lower end of the spleen as the splenic flexure, and passes downward as the descending colon. Reaching the left iliac region on a level with the margin of the crest of the ileum, it makes a curve like the letter "S" which is called the sigmoid flexure, and finally ends in the rectum.

The rectum is from six inches to eight inches long. From its origin at the third sacral vertebra, it descends along the curve of the sacrum, and coccyx, and finally bends sharply backward into the anal canal.

The anus is the aperture leading from the rectum to the exterior of the body. It is guarded by an internal sphincter muscle of the involuntary type and an external sphincter muscle that is voluntary, but both are supplied with nerves from the central nervous system.

XI.

Roentgenology has been a great aid in the study of disorders in the urinary tract. Since the kidneys are slightly greater in density than the surrounding structures their outlines can be shown on roentgenograms through nearly their entire extent. This makes it possible by means of roentgenography to determine their size, shape, and position, their relative density, and the presence of calcareous and other deposits in the form of calculi. With the assistance of the urologist in the performance of pyelography, much other important information with reference to renal disease may be obtained.

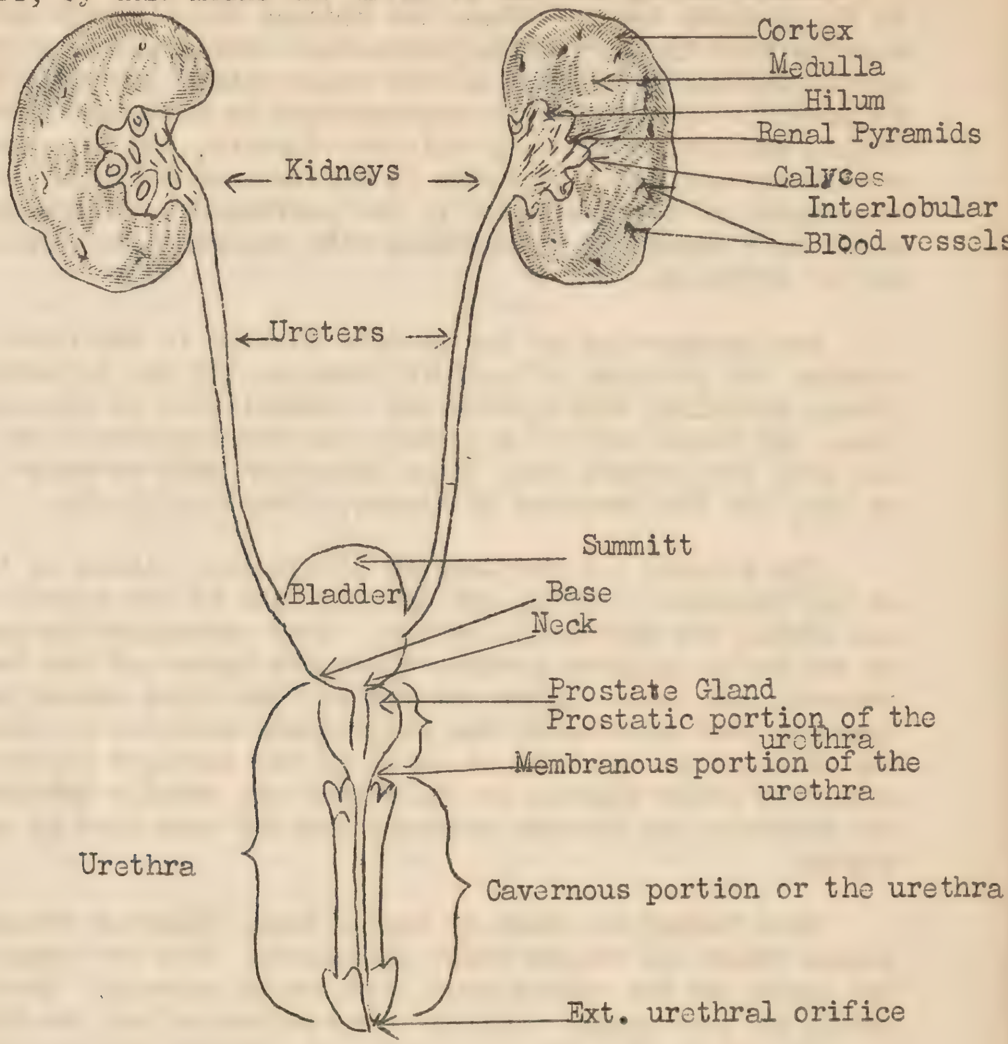
Roentgenography of the ureters usually is undertaken to determine the presence of ureteral stones. By the injection of an opaque solution, dilatitions and abnormalities in diameter, outline, and course can be detected. Roentgenograms of the bladder are made for calculi and, after injection with an opaque solution or air, for the presence of tumors, diverticula, etc.

The kidneys are bean-shaped structures, placed at the back of the abdominal cavity, one on each side of the spinal column and behind the peritoneal cavity. They correspond in position to the space included between the upper border of the twelfth thoracic and third lumbar vertebrae. The right kidney is lower than the left because of the large space occupied by the liver. The kidneys are not held in place by any distinct ligaments, but rather by fatty tissue, in which they are usually imbedded, and the pressure and counter pressure exerted upon them by neighboring organs.

Each kidney is about $4\frac{1}{2}$ inches long, $2\frac{1}{2}$inches braod, $1\frac{1}{2}$ inches thick and weighs about $4\frac{1}{2}$ ounces. They are concave towards the spine and the convex side is directed outward. Near the center of the concave side is a depression called the hilum, which serves as the passageway fro the ureter and for the blood vessels, etc., going to and from the kidney. The outer layer of the kidney is called the cortex while the inner portion is called the medulla. The medulla consists of several conical segments which are called the renal pyramids. Also in the medulla are located the interobular bloodvessels. The apices of the renal pyramids are received into the calyces of the renal pelvis; the bases extend toward the surface of the kidney.

After the waste products are collected in the kidneys they are passed down through the ureters. The ureters, approximately 10 to 12 inches long and about the diameter of a goose quill, connect the kidneys with the urinary bladder and serve as a passageway to convey secretion from the kidneys to the bladder. The ureters do not parallel the spine exactly, but "toe in" gradually from the kidney to the bladder, being closer to the spine at the lower end than at the upper end. The ureters enter the substance of the bladder at about the junction of its posterior,

superior, and lateral surfaces. Slow rhythmic contractions occur in the ureters; by this means the urine is carried to the bladder.



The urine is received into the bladder from the ureters and retained until it is eliminated through the urethra. The bladder is a hollow muscular organ situated in the lower abdominal or pelvic cavity behind the symphysis pubis. It has either a round or ovoid shape, depending upon the amount of distention. The widest part is spoken of as the fundus, and the part where the bladder becomes continuous with the urethra, as the neck.

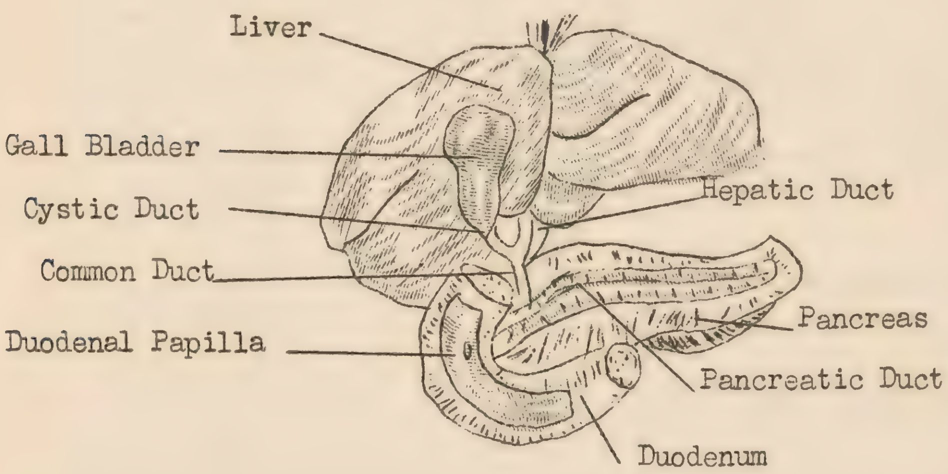
The urethra is the tube which conveys urine from the bladder to the exterior. It differs in the sexes. In the female, it belongs entirely to the excretory system. In the male, it is common to the excretory and reproductive systems, it conveys semen to the exterior, as well as urine. In the male, the urethra consists of three portions. These are the prostatic, membranous, and cavernous portions. The prostatic portion is

about two to three centimeters in length; it passes from the internal urethral orifice to the pelvic floor. It is entirely surrounded by the prostate gland. The membranous portion is that part of the urethra which passes through the pelvic floor or body wall; it extends from the apex of the prostate gland to the bulb of the urethra. It is about one centimeter long. The cavernous portion of the urethra travels in the penis. It is about fourteen centimeters long. It terminates at the external urethral orifice.

XII.

The gall bladder frequently is the seat of infection and often contains stones. Either condition may produce direct or reflex symptoms in the upper part of the abdomen. Since such symptoms so often are reflex and of a vague and indefinite nature, any method of examination that materially assists in detecting the presence of gall-bladder disease is of considerable value. Of these x-ray examination undoubtedly is the most reliable.

The gall bladder is a pear-shaped sac lodged in the gall bladder fissure on the under surface of the liver and about two inches to three inches from the spine laterally. It is about four inches long and about one inch wide. It serves as a reservoir for bile. The gall bladder is connected through the cystic duct and common duct (formed by the junction of the hepatic and cystic ducts) with the duodenum. The gall bladder, radiographically, may appear vertically anywhere from the ninth rib to the crest of the ilium, and laterally from a point overlapping the spine to the outer liver margin.



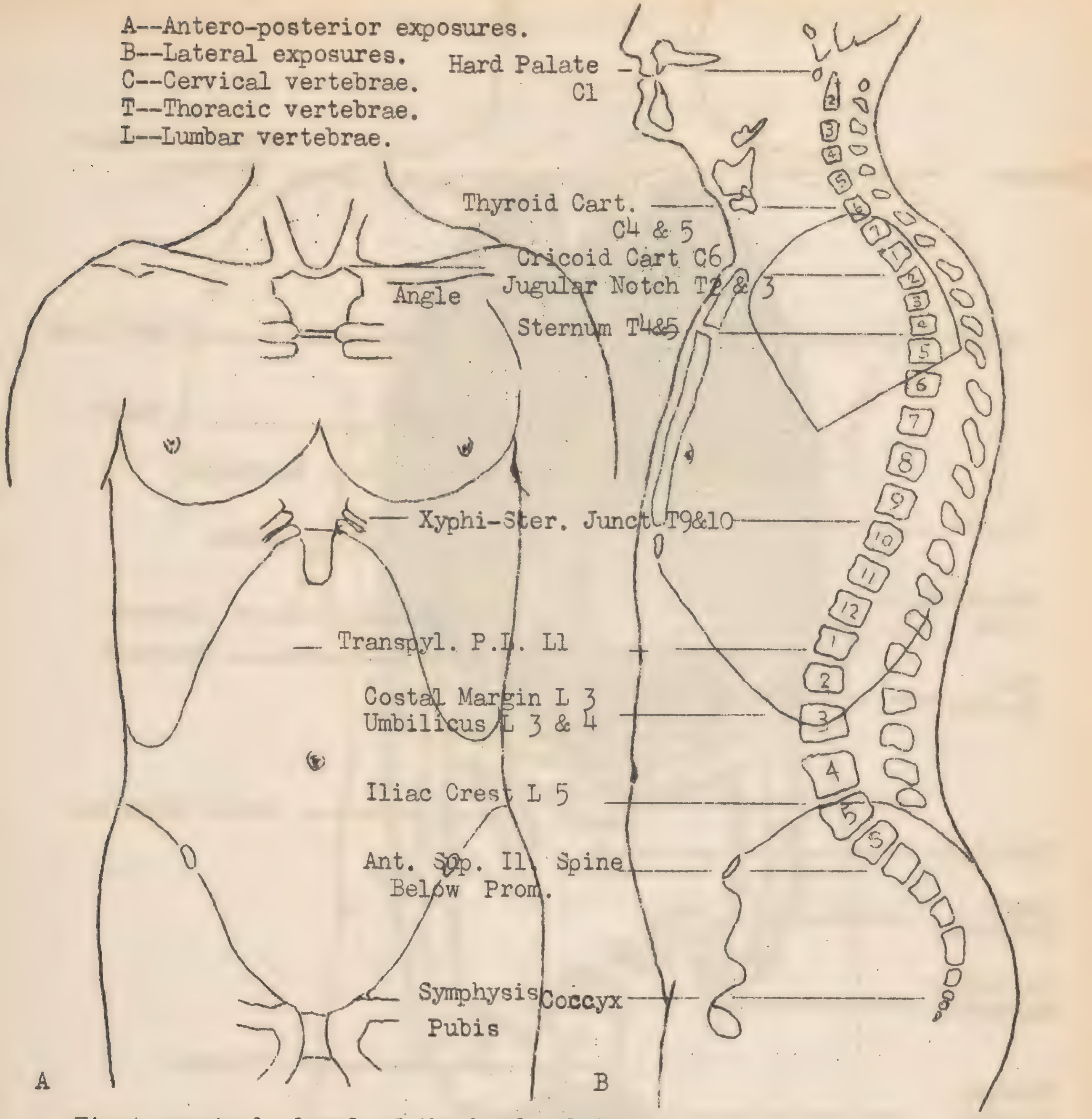
THE LIVER

Hepatic enlargement is the principal condition for which the liver may be examined by x-rays. A large film of the upper part of the abdomen will show the upper surface of the liver clearly outlined against the air-filled lung, separated only by the diaphragm. On such films, especially when made with a Bucky diaphragm, the right border and most of the inferior margin of the right lobe can be identified. Although x-rays are not too helpful in the diagnosis of conditions of the liver, it is important to know something about it because of its close connection with the gall bladder.

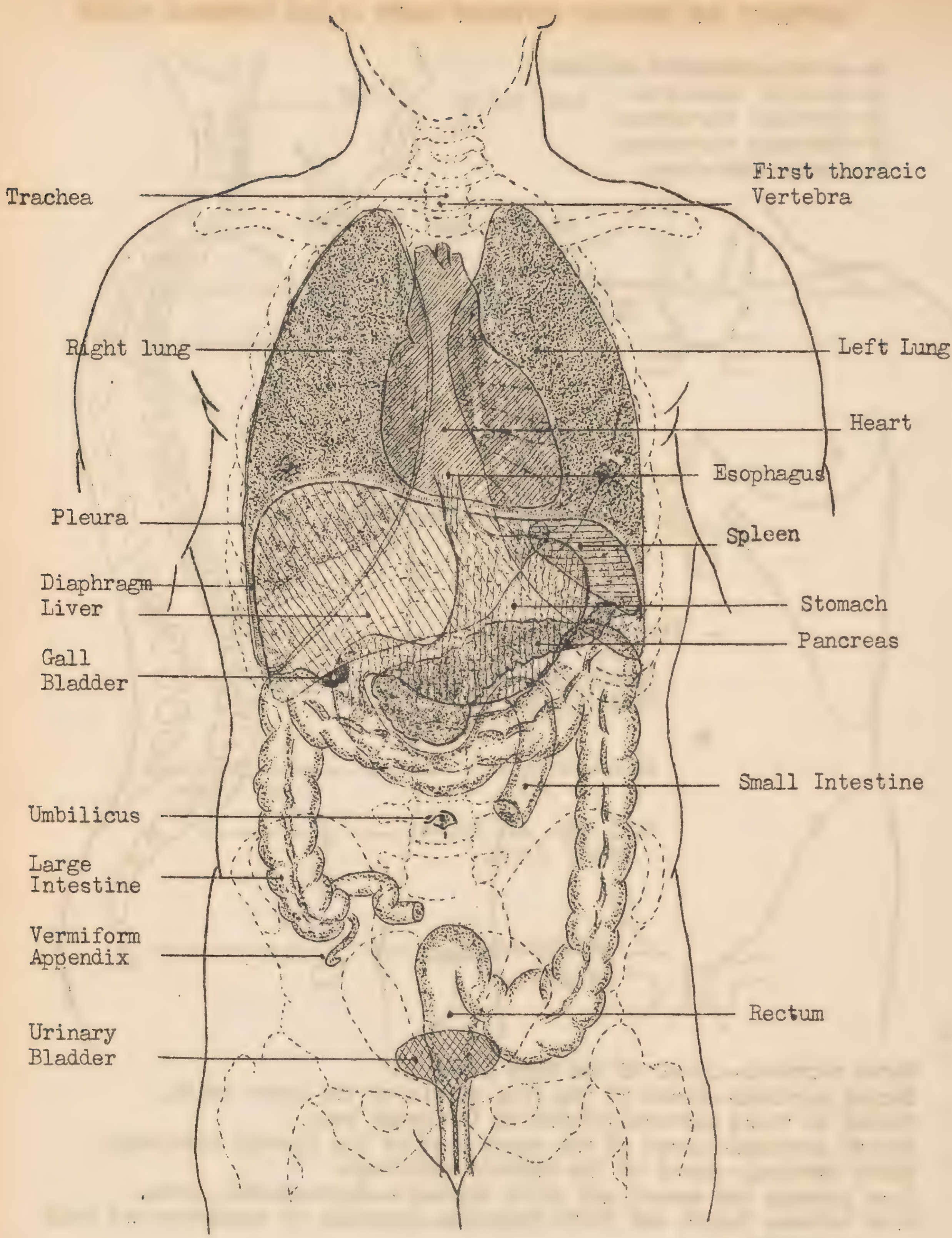
The liver is the largest gland in the body, weighing ordinarily from 50 to 60 ounces. It measures eight to nine inches from side to side, six to seven inches from front to back, and four to five inches from above downward in its thickest part. It is placed directly below the diaphragm in front of the right kidney, the pyloric end of the stomach and upper part of the ascending colon. The upper convex surface fits closely into the under surface of the diaphragm.

The liver is divided into five lobes; the right lobe, which is the largest one, the left lobe, quadrate, caude, and spigelian. It is the lower portion of the right which is often visible in radiography.

LANDMARKS FOR EXPOSING DIFFERENT PARTS OF THE VERTEBRAL COLUMN



First cervical--level of the hard palate.
Second cervical--level of the free margin of the upper teeth.
Second to third cervical--level of the hyoid bone.
Fourth cervical--level of the upper part of the thyroid cartilage.
Sixth cervical--level of the cricoid cartilage.
Disk between the second and third thoracic--Suprasternal notch.
Disk between fourth and fifth thoracic--Junction of manubrium and body of sternum.
Disk between ninth and tenth thoracic--Sternoxiphoid junction.
First lumbar--Transpyloric plane, midway between umbilicus and sternoxiphoid junction.
Disk between third and fourth lumbar--Umbilicus.
Fifth lumbar--Plane connecting anterior superior iliac spines.



SHOWING SOME OF THE THORACIC, ABDOMINAL, AND PELVIC VISCERA

TECHNICAL VOCABULARY

X-RAY

1. abdomen — the portion of the body lying between the thorax and the pelvis.
2. abduct — to draw away from the median line.
3. abscess — a localized collection of pus in a cavity formed by the disintegration of tissue.
4. absorb — to assimilate fluids or other substances from skin or other body tissues.
5. absorption — the act of taking up by suction.
6. acceleration — quickening, as of the pulse or respiration.
7. accessory — additional; supplimentary.
8. acetabulum — cup-shaped cavity in the innominate bone receiving the head of the femur.
9. achondroplasia — a bone disease in which the cartilage is not properly replaced by bone.
10. acoustic — relating to sound or the sense of hearing.
11. acromegaly — a disease marked by the enlargement of the tissues of the face, hands and feet.
12. acromion — the outward extension of the spine of the scapula, forming the point of the shoulder.
13. actinomycosis — a fungus infection.
14. acute — having severe symptoms and a short course.
15. adenoma — tumor composed of glandular tissue.
16. adenopathy — any disease of glands.
17. adherent — stuck together.
18. adhesions — abnormal joining of parts to each other.
19. aerated — filled with air.

20. alimentary - serving as food; nutritious.

21. alinement - to bring into a straight line.

22. alveolar - pertaining to an alveolus.

23. alveolus - terminal air sack of the lung.

24. ammeter - an instrument for the measurement of the quantity of an electric current.

25. amniography - radiography of the embryo for the detection of sex.

26. amorphous - a plastic state of matter having no regular form.

27. anemia - deficient quantity or quality of the blood.

28. anesthesia - loss of feeling or sensation.

29. anatomy - the science of the structure of organized bodies.

30. aneurysm - a sac formed by the dilatation of part of an artery, and filled with blood.

31. angioma - tumor composed of blood vessels.

32. ankylosis - abnormal immobility and consolidation of a joint.

33. anomaly - deviation from normal standard.

34. anterior - refers to the front of a structure or part.

35. anthracosis - a disease of the lungs from prolonged inhalation of fine particles of coal dust.

36. antrum - a chamber or cavity in a bone.

37. anus - distal end and outlet of rectum.

38. aorta - great artery springing from left ventricle.

39. apex - apical - top or pointed end of a conical part.

40. appendix - a small tubular appendage attached to the cecum at its junction with the small bowel.

41. apposition - contact of adjacent parts.

42. arachnoid -like a spider's web.

43. Arceline -a position for x-ray examination of the mastoids.

44. arteriosclerosis -hardening of arterial walls.

45. arthritis -gout or any joint inflammation.

46. articular -of, or pertaining to, a joint.

47. artifact -artificial marks on an x-ray film due to accidents in handling or processing the film.

48. ascending -having an upward course.

49. astenic -characterized by weakness.

50. astragulus -bone of the foot which articulates with the tibia.

51. atelectasis -imperfect expansion or partial collapse of lungs.

52. atresia -absence of a normal opening.

53. atrophic -pertaining to or characterized by atrophy.

54. atrophy -a wasting or diminution of size.

55. atypical -not conforming to the type.

56. auditory -pertaining to the sense of hearing.

57. auricular -pertaining to the ear; or to the auricle of the heart.

58. axilla - the armpit.

59. azygos -unpaired.

60. barium - a metallic element, salts of which are medicinal.

61. benign - not malignant; not recurrent.

62. biceps - having two heads; as the arm and thigh muscles.

63. bicuspid - having two cusps or teeth.

64. bifurcate - forked; forked in shape.

65. bilateral - having two sides.

66. bladder- -membranous sac which contains the urine.

67. bones- -material of the skeleton of most vertebrate animals.

68. bronchiectasis -dilatation of bronchia.

69. bronchioles- _minute bronchial tubes.

70. bronchitis -inflammation of the bronchial tubes.

71. bronchogenic -originating in the bronchi.

72. broncho-pneumonia -a type of lung infection which spreads to the lung from the bronchi.

73. bronchus -air tube which supplies the lung.

74. Bucky-diaphragm -a diaphragm for x-ray work which will prevent the secondary rays from reaching the plate.

75. bunion -a swelling of the bursa mucosa at the ball of the great toe.

76. bursa -a sac or pouch.

77. bursitis -inflammation of the bursa.

78. buttock -the gluteal prominence or a lateral half of the same.

79. calcaneus -heel bone (os calcis).

80. calcification -deposition of calcium salts in the tissues.

81. calcium -a metal,, the bassis of lime which is its oxide.

82. calculus -a stonelike concretion in any organ

83. calibration -charting of the output of voltage for the various buttons of the autotransformer.

84. callus -the osseous material by which union between the ends of a fractured bone is effected.

85. calorie -amount of heat required to raise one kg. of water one degree centigrade.

86. calyx -any one of the cup like divisions of a renal pelvis.

87. cancellous -(tissue) spongy tissue in the bone.

88. cancer — -a malignant tumor made up chiefly of epithelial cells.

89. capacity — -used in electricity to indicate the fullest extent to which a condense can be charged.

90. carcinoma — -cancer of epithelial origin.

91. cardiac — -pertaining to the heart.

92. cardiophrenic — -(angle) the angle between the margin of the heart and the diaphragm.

93. caries — -molecular decay of bone.

94. cartilage — -the structure covering the ends of long bones to form joints.

95. caseous — -cheesy; cheeselike, as in caseous consolidation of tuberculosis.

96. cassette — -a holder for x-ray film, usually with double intensifying screens.

97. catarrhal — -inflammation of a mucous membrane.

98. catheter — -small calibre rubber tube for insertion into the bladder or other cavity.

99. cathode — -the negative terminal of an electrical apparatus, such as an x-ray tube.

100. caudal — -toward lower end of the body.

101. cavity — -a hollow or space.

102. cecum — -the proximal part of the large intestine.

103. central — -within the center of.

104. cephalic — -pertaining to the head.

105. cerebral — -pertaining to the cerebrum of the brain.

106. cervical — -pertaining to the neck.

107. cervix — -the neck; any necklike part.

108. chalky — -the quality of a radiograph which presents an extreme degree of contrast between the highlights and shadows.

109. characteristic -(radiation) the type of secondary radiation resulting when rays from an x-ray tube strike inorganic substances.

110. cholecystitis -inflammation of the gall bladder.

111. chondritis -inflammation of cartilage.

112. chondroma -a benign cartilaginous tumor.

113. choroid -(plexus) a network of blood vessels in the inner wall of the lateral ventricles of the brain.

114. chronic -not acute; long continued.

115. circuit -the course of an electric current.

116. clavicle -the collar bone.

117. clinoid -(processes) small bony processes adjacent to the sella turcica in the skull.

118. coccyx -small bone below the sacrum.

119. colitis -inflammation of the colon.

120. colostomy -artificial opening in the colon.

121. collapse -to fall together.

122. comminute -to splinter.

123. complete -a fracture which extends completely through the bone.

124. compound -a fracture of bone which pierces the skin.

125. compression -a fracture in which the spongy portion of the bone is compressed.

126. condenser -an electrical apparatus to store up an electrical charge.

127. condyle -rounded eminence at the articular end of bone.

128. congenital -present at birth.

129. congestion -abnormal accumulation of blood in a part.

130. connective -(tissue) the cellular fibrous tissue which forms a network between the various structures of the body.

131. consolidation -solidification, as of a lung in pneumonia.

132. constriction -a narrowing of a lumen or pneumonia.

133. contraction -to become shorter or smaller.

134. contrast -the difference in density between the highlights and shadows.

135. coracoid -(process) the hooklike process projecting from the scapula for muscle attachments.

136. coronal (plane) -plane parallel to the front of the body.

137. coronoid -(process) a projection of bone on the upper portion of the ulna.

138. corpus -body.

139. cortex -the outer gray matter of the brain.

140. costal -pertaining to the ribs.

141. costophrenic -(angle) the angle formed by the ribs and the diaphragm.

142. cranial -pertaining to the head.

143. crater -hole or pit.

144. crest -a ridge of bone.

145. cuspid -teeth located between the lateral incisors and the first bicuspid tooth.

146. cutaneous -pertaining to the skin .

147. cyanosis -deficient oxygenation of the blood resulting in bluish appearance of the skin.

148. cyst -any sac containing a liquid.

149. cystitis -inflammation of the bladder.

150. cystogram -a roentgenogram of the urinary bladder after distension with a medium of different density.

151. defecation -discharge of the feces.

152. degenerative -pertaining to the change of tissue to a lower or less functionally active form.

153. density -the compactness of a substance.

154. dental -pertaining to the teeth.

155. depressed -(fracture) a fracture of a flat bone in which one edge is depressed below the other.

156. descending -(colon) the portion of the colon which descends from the splenic flexure along the left side. of the abdomen.

157. detail -the clearness in the radiograph of the finer structures.

158. developer -the solution used for the development of photographic and x-ray films.

159. diagnosis -the art of determination of the character of a disease.

160. diaphragm -the flat muscular structure which forms a partition between the abdomen and chest.

161. diastole -the resting stage of the heart.

162. digestion -the conversion of food into assimilable matter.

163. dilated -distended

164. dilatation -enlargement.

165. Diodrast -a drug used for intravenous urography.

166. discrete -well defined and clear cut in appearance.

167. dislocation -abnormal relationship of structures.

168. distal -farther away from the central portion of the body

169. distance -distance between the focal spot of the target and the film.

170. distension -enlargement.

171. distortion -variation from normal contour.

172. divergence -radiating outward from any point from the source of radiation.

173. dorsal -pertaining to the back.

174. duodenal -pertaining to the duodenum.

175. duodenum -first portion of the small intestine into which the stomach empties.

176. ectopic -misplaced.

177. edema -swelling due to accumulation of the fluid in the connective tissue.

178. edentulous -without teeth.

179. effective -(voltage) the average voltage effective over the period of any phase of an electric current.

180. effusion -fluid filling a cavity of the body.

181. electric -pertaining to electricity.

182. electro-magnet -a magnet produced in a core by iron by an electric current passing through the coils of wire wound around the iron core.

183. electrode -a terminal of a conductor of electricity.

184. electron -the unit of negative electricity.

185. embolism -the process by which a portion of a blood clot breaks loose into the blood stream.

186. embryo -the earliest period of development of an organism.

187. emphysema -overdistension of the tissues with air.

188. emphema -pus in the pleural cavity.

189. emulsion -the chemical coating of a photographic film.

190. encephalography -a roentgenographical photograph of the brain

191. encroachment -invasion of one tissue by another.

192. enema -injection of fluid solutions into the large bowel.

193. epicondyles -a bony eminence above a condyle.

194. epiglottis -cartilaginous lid of the larynx.

195. epiphysis -the structure at the end of a long bone from which it grows.

196. erosion -disintegration of structure; and eating away.

197. esophagus -the muscular tube that conveys food from the pharynx to the stomach.

198. ethmoid -the air cells in close proximity to the nasal cavity.

199. etiology -cause, of a pathological state or disease.

200. eversion -outward rotation.

201. excretion -the process of excreting.

202. exostosis -an outgrowth of bone.

203. expiration -blowing air out.

204. exposure -the subjection of a film to the effects of light or x-rays.

205. extension -straightening out of a part.

206. external -outside.

207. extravasation -the escaping of blood, or other body fluids from their natural channels into the surrounding tissues.

208. extrinsic -having origin outside the structure or organ involved.

209. exudate -substance that has oozed into the tissues.

210. facet -a small smooth area on a bone usually for articulation.

211. fecalith -small calcium deposit in the walls of the intestine.

212. feces -excrement discharged from the bowels.

213. femur -the large bone of the thigh.

214. fibrosis -the replacement of normal tissues with fibrous tissues.

215. fibula -the smaller of the two bones of the lower leg.

216. filter -a sheet of metal through which the x-rays go before striking the object to be examined or treated.

217. fissure -division of the lung.

218. fistula -a false tract into the tissues.

219. flatus -gas in the intestines.

220. flexion -to double up by contraction of the muscles.

221. fluoroscope -an instrument for examining the deep structures of the body by means of roentgen rays.

222. fluoroscopy -examination by means of the fluoroscope.

223. foramen -an opening on a bone for the transmission of vessels, nerves or other structures.

224. fossa -a hollow depression in a bone.

225. fracture -a break in the continuity of a bone.

226. frilling -separation of the emulsion from the edges of a film.

227. frontal -pertaining to the front portion of the body.

228. function -to carry on the work normally required of a part.

229. gall bladder -the reservoir for bile.

230. gangrene -necrosis of the tissue plus putrefaction.

231. gastric -pertaining to the stomach

232. glenoid -a pit or a socket

233. granulation -formation in wounds of small rounded flesh masses

234. greenstick (fracture) -an incomplete fracture with one side of the bone broken and the other side intact.

235. grid -a wire meshwork used in radiology to cut down the secondary radiation.

236. hematuria -blood in the urine.

237. hepatic -pertaining to the liver.

238. hernia -the projection of a structure through a weak point in a confining membrane.

239. hilum (hilus) -root of the lung.

240. homogeneous -having similar uniform construction.

241. hour-glass stomach -a stomach which is constricted in the middle.

242. humerus -the long bone in the upper arm.

243. hydronephrosis -overdistention of the kidney pelvis with urine.

244. hyperplastic -associated with the overgrowth of tissue.

245. hypertrophic -excessive growth of tissue.

246. hypertrophy -the overgrowth of tissue.

247. idiopathic -of unknown origin

248. ileum -the third portion of the small intestine.

249. ileus -an obstruction to the normal flow of the intestinal contents.

250. ilium -the flaring portion of the hip bone.

251. image -the impression made on an x-ray photographic film by x-ray or light.

252. impacted -lodged firmly in place.

253. imcomplete (fracture) -a fracture that does not extend completely through a bone.

254. induction -the production of an electrical current in a coil by close subjection to another bearing an electric charge

255. infection -the invasion of body tissues by pathogenic organisms.

256. inferior -below.

257. infiltration -the permeation of a tissue by substances not normal to it.

258. inflammation -a natural reaction of the body to injury or irritation.

259. infraclavicular -below the clavicle

260. inguinal (region) -the fold between the abdomen and thigh.

261. innominate (bones) -the large irregular pelvic bones.

262. inspissated -thickened by absorption of fluid content.

263. interstitial -located in the interspaces of a tissue.

264. intensifying(screen)-a screen composed of fluorescent material placed in close contact with an x-ray film to intensify the action of x-rays.

265. intercostal -between ribs.

266. intermittent -having a time interval between impulses.

267. interspace -the space between two structures, usually the ribs.

268. intertrochanteric -(fracture) a fracture extending between the trochanters of the upper end of the femur.

269. intervertebral(disc)-the cartilaginous discs between the vertebra.

270. intraarticular -within the joint.

271. intrinsic -having origin within the structure or organ involved.

272. intussusception -pushing in of one segment of the bowel into another.

273. involucrum -the periosteal new bone formed to replace the destroyed bone in osteomyelitis.

274. Iodeikon -the drug used for visualization of the gall bladder.

275. Iopax -a drug used for intravenous pyelography.

276. irradiate -to subject a substance to radiation.

277. intra vs. inter -into vs between

278. iso- -prefix meaning the same or similar.

279. -itis -suffix meaning inflammation of.

280. jejunum -the second portion of the small intestine.

281. junction -the point of meeting or uniting.

282. Kenetron-(tube) -a valve tube for the rectification of high voltage current.

283. kymograph -x-ray apparatus used to record the range of motion of various chambers of the heart through the cardiac cycle.

284.	kyphosis	-curvature of the spine with convexity backward. (humpbacked)
285.	labryinth	-communicating cavities and canals making up the inner ear.
286.	lacerated	-cut or incised by a sharp instrument.
287.	lacrimal	-(duct) (gland)- tear.
288.	lambdoid	-(suture)- the suture between the parietal bones and the occiput of the skull.
289.	laminated	-having many thin layers .
290.	laminograph	-x-ray apparatus used to radiograph a thin layer of tissue at any depth in the body without interference with the intervening structures.
291.	latent (image)	-the image produced on an x-ray film by the action of light or x-rays before development.
292.	latitude	-the range of exposure of an x-ray film permissible for good diagnostic result.
293.	lesion	-any local pathological condition.
294.	leucocyte	-white blood cell.
295.	ligament	-a strong band of fibrous tissue usually found at a joint.
296.	linear	-like a line.
297.	Lipiodol	-an opaque oil used for injection into the body cavities for the purpose of x-ray examination.
298.	lobar	-pertaining to the lobes of the lung.
299.	localization	-the accurate measurement of the location of foreign bodies with relationship to the surface and adjoining structures.
300.	longitudinal	-extending along the long axis of the bone.
301.	lordosis	-curvature of the spine with convexity forward.
302.	lumbar (spine)	-the portion of the spine below the thorax which forms the back support of the abdominal cavity and is attached to the sacrum below.

303. lumen -the channel of a tubular structure.

304. luxation -abnormal slipping of one structure on another at a joint or place of natural division.

305. lymphatics -the lymph vessels which collect the lymph from the tissues.

306. Lysholm grid -a stationary grid of fine lead strips which is used like a bucky diaphragm.

307. macroscopic -that which can be seen with the unaided eye, without the use of a microscope.

308. magnetic -(field) the field of magnetic force emnating from a magnet.

309. mal- -prefix, meaning proper.

310. malignant -tending to progress from bad to worse.

311. malleolus -either of the two rounded prominences on either side of the ankle joint.

312. mandible -the lower jaw bone.

313. manubrium -the upper most piece of the sternum.

314. Marie- Strumpell's disease -a disease of the spine resulting in complete ankylosis.

315. masks -lead shields for shielding the field of examination so that further x-ray exposure maybe utilized to blacken the surrounding field.

316. mastoiditis -inflammation of the mastoid cells.

317. maxilla -the upper jaw.

318. maxillary sinus -one of the accessory nasal sinuses located in the maxillary bone.

319. meatus -the opening at the end of a canal.

320. mediastinum -the medium septum between the lateral cavities of the thorax.

321. medullary canal -the inner hollow portion of a long bone containing the marrow.

322. membrane -a thin layer of tissue covering a surface.

323. meninges -the lining membrane of the spinal canal and skull.

324. mesentery -the fold by the intestines are attached to the posterior wall of the abdominal cavity.

325. metacarpal (bones) -the short bones of the hand extending between the wrist and fingers.

326. metatarsal -the short bones of the foot between the tarsal bones and the phalanges.

327. milliammeter -a meter that measures milliamperage of current.

328. minimal -the smallest recognizable amount.

329. mobility -the degree of movability of a structure.

330. motility -the rate of motion such as, the peristaltic action of an organ.

331. mucosal -pertaining to the mucous membrane.

332. mucous membrane -any membrane or lining of a cavity of the body which secretes mucus.

333. mulitple- (fracture) -more than one fracture.

334. myositis ossificans -calcium deposits in the muscles.

335. nasal -pertaining to the nose.

336. nausea -the sensation of a desire to vomit.

337. navicular -a small bone of the wrist.

338. necrosis -death of tissue.

339. negative -used in photography to indicate the reversed image on a photographic film formed in photographing an object.

340. Neoiopax -a drug used in intravenous urography.

341. neoplasm -new growth; tumor.

342. nephroptosis -the dropping of the kidney from its normal location.

343. neurogenic -pertaining to or having nerve origin.

344. nodular -having a bumpy consistance.

345. nonossifying -showing no tendency to form bone.

346. nucleus pulposus -the shock absorber between the vertebra.

347. nutrient -supplying nourishment.

348. oblique -(fracture) extending obliquely through a bone.

349. obliterate -to completely remove.

350. obstruction -interference with normal flow.

351. occiput -the flat bone which forms the back of the head.

352. occlusion -closure of a passageway or cavity.

353. odontoid -tooth like; (process) tooth-like projection of the second cervical vertebra where it articulates with the first cervical vertebra.

354. olecranon process -the heavy hook-like projection of bone forming the upper end of the ulna, which articulates with the lower end of the humerus.

355. omentum -folds of the peritoneum connecting the stomach and transverse colon, hanging down in front of the intestines like an apron.

356. opacity -an object imperious to light.

357. opaque -impenetrable by light.

358. optic -pertaining to the eye.

359. oral -pertaining to the mouth.

360. orbit -the boney cavity of the eye.

361. organic lesion -a pathological condition pertaining to a part of the body having special function

362. orifice -opening

363. ossification -changing into bone.

364. osteitis -inflammation of a bone.

365. osteoblastic -bone forming.

366. osteoclastic -bone destroying.

367. osteogenic sarcoma -a malignant tumor arising from the bone.

368. ovaries -female sex organs (gonads)

369. overexposure -too great exposure of an x-ray film to x-rays.

370. overpenetration -too great penetration (kilovoltage) used in radiography.

371. palmar -referring to the palm of the hand.

372. pancreas -a glandular organ located posterior to the stomach the secretion from which aids in digestion of sugars.

373. para- -prefix meaning running along; adjacent to.

374. paralysis -loss of nerve control of the muscles.

375. parenchyma -the outer functioning portion of the lung containing the air sacs.

376. parenchymatous -pertaining to the parenchyma.

377. parietal -of or pertaining to the walls of a cavity.

378. parotid gland -one of the salivary glands situated in the soft tissues just in front of the ear, emptying its secretion into the mouth.

379. patella -the knee cap.

380. pathology -the science which deals with diseased structures of the body.

381. pelvimetry -measurement of size of the bony pelvis.

382. pelvis -the basin formed by the innominate bones, sacrum, and coccyx.

383. penetration -the ability of radiation to extend down into and go through substances; as, the penetration of x-rays.

384. perforating -breaking through.

385. peri- -prefix meaning around.

386. peribronchial markings -the linear markings seen in a film of the lungs due to branching of the bronchi and their accompanying peribronchial structures.

387.	pericardium	-the membrane covering the heart and lining the pericardial cavity.
388.	perinephritic	-around the kidney.
389.	perimeum	-the region between the upper portion of the thighs extending from the pubic arch to the coccyx.
390.	periosteum	-the fibrous covering of a bone.
391.	peripheral	-at the outer edge of.
392.	peristalsis	-a wave-like contraction of the gastro-intestinal tract by which its contents are moved forward.
393.	peritoneum	-the serous membrane which lines the abdominal wall.
394.	peritonitis	-inflammation of the peritoneum.
395.	petrous bone	-the dense pyramidal process of the temporal bone which houses the auditory canal.
396.	phalanges	-the bones of the fingers or toes.
397.	pharynx	-the portion of the throat connecting the mouth to the esophagus.
398.	phleboliths	-small rounded calcium deposits in the walls of the veins.
399.	phrenic	-pertaining to the diaphragm.
400.	physiological effect	-the effect on living tissues.
401.	pituitary gland	-a small glandular structure about the size of a pea which hangs down from the under surface of the brain into the pituitary fossa.
402.	pleura	-membrane covering the lung and lining the pleural cavity.
403.	pleural effusion	-fluid filling the membranous sac covering the lung and lining the chest.
404.	plexus	-a network; as, a plexus of nerves.
405.	pneumo-	-prefix indicating air-containing.

406. pneumonia -an acute infectious disease of the lungs.

407. pheumothorax -air in the thoracic (chest)cavity

408. poly- -prefix meaning many.

409. polycystic kidney -a congenital condition in which there are many cysts throughout the kidney substance.

410. polypi -small pedunculated growths.

411. pregnancy -the condition of the female mammal when with child.

412. proliferation -multiplication of cells.

413. pronation -rotating into a prone position; turning of the hand with palm downward.

414. prostate -a gland surrounding the neck of the bladder and urethra in the male.

415. proximal -nearest the trunk, center, or median line.

416. psoas muscles -heavy muscles of the spine.

417. ptosis -sagging down in an unnatural position.

418. pubis -the bones forming the anterior portion of the pelvis.

419. pulmonary -pertaining to the lungs.

420. pulsating -recurring in beats but not having a regular cycle; for example, pulsating current in an x-ray tube.

421. purulent -consisting of or containing pus.

422. pus -the fluid resulting from bacterial infection, and body tissue elements attempting to combat the infection.

423. pyelitis -inflammation of the kidney pelvis.

424. pylorus -the lower end of the stomach just before it joins with the duodenum.

425. pyo- -prefix, pus.

426. pyonephrosis -pus in the kidney pelvis.

427.	radiologist	-a physician who uses all forms of radiant emergy (x-rays, radium rays, etc.) in the diagnosis and treatment of disease.
428.	radiology	-the science which deals with the use of all forms of radiant energy in the diagnosis and treatment of disease.
429.	Radium	-a radioactive element used in the treatment of disease.
430.	radius	-the larger of the two bones in the forearm.
431.	ramus	-a branch or process of a bone or vessel.
432.	rarefied area	-an area of lessened density.
433.	rectify	-to change from an alternating to an undirectional current.
434.	recto-vaginal	-pertaining to rectum and vagina.
435.	recto-vesicle	-pertaining to the rectum and bladder.
436.	rectum	-the terminal pouch-like expansion of the large bowel.
437.	regurgitation	-the return flow of fluid in the direction opposite to normal flow.
438.	renal	-pertaining to the kidney.
439.	resistance	-a substance which offers an impediment to the flow of an electric current.
440.	reticular	-having the appearance of network.
441.	retro-	-prefix, meaning back, against, behind.
442.	retrograde	-back or against the natural flow.
443.	roentgenography	-use of x-rays in taking x-ray films of a part.
444.	roentgenology	-the science which deals with the use of x-rays in the examination and treatment of disease.
445.	sacralization	-enlargement of a transverse process of the fifth lumbar vertebra with encroachment on the sacrum.

446. sacro-iliac joint -the joint between the sacrum and iliac bone on either side.

447. sacrum -the wedge-shaped bone at the lower end of the spine which forms the key stone for the arch of the pelvis bones.

448. sagittal plane -a plane which divides the body in the mid-line into the right and left sides.

449. scapula -the "Shoulder blade" forming joints with the humerus and clavicle.

450. scattered radiation -the type of secondary radiation which results when x-rays strike an organic substance (having a lower atomic weight than aluminum)

451. sclerosis -hardening of the tissues, usually of the interstitial tissue, or bone.

452. scoliosis -lateral curvature of the spine.

453. sella turcica -(turkish saddle) the saddle-like bone structure at the base of the skull which shelters the pituitary gland.

454. serous fluid -clear watery fluid secreted by serous membranes of the body.

455. sesamoid bone -a bone formed in a tendon.

456. sigmoid -the "S"-shaped portion of the descending colon as it crosses the pelvis brim.

457. silicosis -a disease of the lungs from prolonged inhalation of fine dust particles of silica.

458. sinus -a natural cavity in the bone containing air.

459. Skiodan -a drug used in urography for both intravenous and retrograde methods.

460. spasm -involuntary continuous contraction of a muscle.

461. sphenoidal sinus -one of the accesory nasal sinuses.

462. sphincter -a circular muscle which, by its contraction produces closure of a canal or pouch.

463. spicule -a small fragment; as a small spicule of bone.

464.	spine	-the vertebrae composing the back bone.
465.	spondylolisthesis	-luxation of the vertebrae, usually of the fifth lumbar foward on the sacrum.
466.	spontaneous	-without apparent cause.
467.	sprain	-tearing of ligaments.
468.	stellate	-star-shaped.
469.	stenosis	-a constriction of the lumen or opening of a canal.
470.	stereoscope	-an instrument consisting of two illuminating boxes for the illumination of two separate radiographs taken from two positions of the target, a distance equivalent to the interpupillary distance, two and one-half inches.
471.	sternum	-breast bone composed of three segments; manubrium, body (gladiolus), Xiphoid (ensiform) process.
472.	stricture	-an abnormal narrowing of a duct or passage
473.	sub-	-prefix, meaning below.
474.	subdiaphragmatic	-under the diaphragm.
475.	subphrenic	-under the diaphragm.
476.	superior	-above
477.	supination	-turning of hand with palm uppermost.
478.	suppurate	-to form pus.
479.	supra-	-prefix, meaning above.
480.	suture	-line of union between bones of the skull.
481.	symphysis	-the union of two paired bones, as, symphysis pubis.
482.	syphilis	-a constitutional disease usually acquired by venereal infection with can any of the structures or tissues of the body.
483.	systole	-the stage of contraction of the heart.

484. tele- -prefix, at a distance.

485. temporomandibular joint -joint between temporal bone and lower jaw located just anterior to the ear.

486. testes -male sex glands, gonads.

487. therapy -(treatment) used in radiology to indicate treatment with radium and x-rays.

488. thoracic -(dorsal) pertaining to the chest; as thoracic vertebrae.

489. Thorotrast -a drug used similarly as thorium dioxide.

490. thrombus -the clotting of blood within a vessel.

491. thymus -a ductless gland located in the chest beneath the upper portion of the sternum; in children up to two years of age.

492. thyroid -(gland) a ductless gland located in the neck, having to do with the metabolism of the body.

493. tibia -the larger of the two bones of the leg.

494. torsion -twisting.

495. trachea -the wind pipe by which air is introduced into the lungs.

496. traction -pull applied to the ends of a fracture for the purpose of adjusting the fragments and overcoming shortening.

497. transverse -extending out laterally, or sidewise as, transverse processes of vertebrae.

498. trauma -injury.

499. traumatic -due to injury.

500. trochanter -a heavy rounded projection of bone for attachment of muscles.

501. trochlea -the inner portion of the articular surface of the lower end of the humerus for articulation with the ulna.

502. tubercle -smaller rounded projections of bones.

503. tuberculosis -a disease produced by the tubercle bacillus.

504.	tumor	-an abnormal swelling
505.	ulcer	-an open sore on a cutaneous, or mucous surface.
506.	ulna	-the smaller of the two bones of the forearm.
507.	umbilicus	-the navel.
508.	union of a fracture	-growing together of two ends of a fracture with new bone formation.
509.	ununited	-not united.
510.	ureter	-the tube which conveys the urine from the kidney to the bladder.
511.	ureteral catheterization	-introduction of small ureteral catheters through a cystoscope into the ureters.
512.	urethra	-the tube which conveys the urine from the bladder to the outer orifice.
513.	uterus	-womb.
514.	ventral	-front
515.	ventricles	-the reservoirs, or spaces, in the brain.
516.	vesicle	-bladder; the sac or pouch for the collection of bile, or urine; a small blister of the skin.
517.	visceral	-in close relationship to a viscus or organ.
518.	viscus	-a body organ; such as, the liver, spleen, or kidney.
519.	volvulus	-obstruction from twisting of a loop of bowel.
520.	Water's position	-the vertico-mental position for examinatiom of the nasal sinuses.
521.	xiphoid (ensiform) process	-the small triangular bony process forming the lower end of the sternum.
522.	zygomatic	-the bony arch which provides the prominence of the cheek bone.

X-RAY REVIEW QUESTIONS

1. Why do connections on the filament circuit have to be tight? Why may they be locse on the high tension side?

2. What means are there to determine the size of the focal spot?

3. What is the importance of the size of the focal spot? What are the advantages and the disadvantages of a small focal spot?

4. Problem: Given a tube whose maximum capacity is 100 MA at 84 KVP for $\frac{1}{2}$ second. Under what conditions would you be justified in using 100 MA for 1 second?

5. What measuring devices are used in an x-ray machine?

6. If x-rays are invisible, how may there presence be detected?

7. What is the fundamental relation between the KV impressed on an x-ray tube and the quality of the mergent beam?

8. Upon what does the penetrability of the x-ray depend? How is a more penetrating ray produced?

9. What methods are there for determining the accuracy of your timer?

10. What is the usual method of measuring: Quality
Quantity of an x-ray beam?

11. How is the wave length of x-rays governed?

12. If x-rays penetrate all materials, how then is it possible to apply them to radiography?

13. What is a transformer? Draw a diagram of same.

14. What is meant by ratio of a transformer?

15. Can direct current be used in operating an x-ray transformer?

16. What governs the voltage which passes across the tube and how is it varied?

17. What is an intensifying screen? Of what is it constructed? What property does it depend on?

18. What is meant by good screen contact? How do you test for it? What is its importance?

19. What is: Primary radiation? Secondary radiation? Characteristic radiation?

20. Name the divisions of the spine and state how many vertebrae are in each division.

21. What apparatus is used in the localization of foreign bodies of the eye? Give brief description.

22. How many teeth in the adult mouth and what are they?

23. In determining the presence or absence of a fracture of the zygoma where may the film be placed and the tube centered to reveal both zygoma?

24. What bones enter into the shoulder joint?

25. What bones enter into the formation of the pelvis and which of these articulate with the spine?

26. Where does the esophagus begin and where does it end?

27. What term is used to designate movement which is opposite to that of pronation?

28. How many ribs are there and to what portions of the spine do they attach? To what are they attached anteriorly?

29. Name the groups into which the bones of the hand are divided. What is meant by sesmoid bones?

30. What are various positions used in the examination of the lungs?

31. What are the common positions used for the examinations of the para-nasal sinuses and what is the purpose of each?

32. Name the bones that enter into the knee joint.

33. Where are the following: Symphysis pubis.
Xiphoid process.
External occipital protuberance.
Iliac crest
Parietal bones.

34. What is a film artefact?

35. What is meant by developer? Of what is it composed? Explain the action of each chemical used.

36. What is meant by latitude of an x-ray film?

37. What are the methods for determining the proper developing time?

38. How would you test a safe light for safety?

39. Discuss briefly the construction of an x-ray film. Of what chemicals is its sensitive surface composed? What action does light have upon the emulsion?

40. What is meant by: contrast, detail, density?

41. What methods may be used to secure immobilization of parts?

42. Why is it necessary to have close approximation of parts to film?

43. When good radiographic detail cannot be secured, due to inability to approximate the part close to the film, what change in technic may be employed to secure detail?

44. Where two views at right angles to each other cannot be made, what other method do we have for securing a conception of the third dimension?

45. Describe briefly the principle of stereoscopic examination.

46. What precautions should be used where it is necessary for someone to assist in immobilizing the patient?

47. How much radiation can be given a patient with safety in radiographic work?

48. Is it proper for the technician to discuss the pathology, as shown in the x-ray, of any patient examined, with the personnel of the hospital, or in fact anyone?

49. If a patient, upon whom you had made a technical x-ray examination, inquires of you what the film discloses, what would your answer be?

50. Would you talk over symptoms with a patient, or his relatives, and criticize the examination ordered by the patient's physician?

51. When the gall bladder, on visualization, is close to the spine, what position may be taken to bring out this view?

52. What is meant by accessory nasal sinuses? How many are there? Name them

53. What is meant by true and false ribs?

54. What causes bucky lines on a film and how may it be corrected?

55. What is the function of the Bucky?

56. Why is Bucky distance such an important factor?

57. What are the advantages and the disadvantages of a Bucky?

58. Discuss the advisability of technicians holding, or assisting in holding patients during treatment?

59. Is there any difference in the chemical composition of intensifying and fluoroscopic screens?

60. How would you mount a pair of intensifying screens?

61. What is the electron theory?

62. Define: Volt Watt
Ampere Milliampere
Ohm Kilovolt K.V.P.

63. What is EMF? What is its practical unit and how is it ordinarily measured?

64. Draw a typical A.C. wave, mark off one cycle.

65. What is self-rectification and what are its advantages and disadvantages?

66. What is a rectified current? Types?

67. Name three methods of rectification.

68. How is K.V. varied in the x-ray machine? How is tube current varied?

69. What is an auto-transformer? How is it constructed?

70. What is a rheostat? How constructed? What function might it serve in an x-ray machine?

71. What are the usual methods of measuring voltage, both high and low tension?

72. Describe an x-ray tube.

73. What do you understand by the term "hot cathode" tube?

74. What is the cathode stream?

75. Describe how an x-ray tube functions.

76. What produces gas in a tube?

77. What governs the MA which passes across the Coolidge tube and how is it varied?

78. Trace the line current from the switch to the tube in a simple machine.

79. What kind of current does the field gasoline generator produce?

80. What is a lode stone? What is a permanent magnet?

81. How may the magnetic field of a magnet be demonstrated?

82. What constitutes an electric current and what is the explanation of its production?

83. What relationship do Watts, Volts and Amperes have to each other?

84. How may electricity be made from magnetism?

85. How may an electric current produced from magnetism be increased to sufficient amount to be useful in the production of x-rays?

86. Show by graphic curves the difference between direct and alternating current.

87. What is a synchronous motor and for what is it used in the modern x-ray machine?

88. What is a choke coil and how does it operate?

89. What conditions are necessary for the production of x-rays?

90. In a hot cathode tube what effect does an increase of heat of the filament have on the milliamperes delivered to the x-ray tube?

91. Of what significance is fluorescence in the hot cathode x-ray tube during operation?

92. What causes heating of the target during operation of the tube?

93. What characteristics must a metal have to be a good substance for the target of the x-ray tube?

94. Explain the theory of operation and advantages of a "rotating target" tube.

95. What are x-rays and what are their characteristics as they emerge from an x-ray tube?

96. What are the similarities and the differences of light rays and x-rays?

97. What conditions are necessary for the satisfactory examination of any structure of the body?

98. Under what circumstances are x-rays visible? Can they be reflected, refracted, or focused by ordinary means?

99. What is meant by Roentgenography, and upon what principle does it depend?

100. What is fluoroscopy and upon what general principle does it depend?

101. Does a fluoroscopic screen emit light or x-rays when activated?

102. Give advantages and disadvantages of Roentgenographic and fluoroscopic examination.

103. What physiological manifestations develop from exposure of the skin to x-rays?

104. How may the ionization of gases by x-rays be demonstrated and of what value is such a determination in the practice of Roentgenology?

105. What changes in chemicals are due to x-ray exposure?

106. What factors govern the intensity of action produced on an x-ray film?

107. What is meant by photographic effect? How does it vary with a change in MA, KV, Time, and distance?

108. What single equation expresses the relationship of all factors concerned in photographic effect?

109. What are the ranges of useful MA and KV for fluoroscopy, roentgenography and therapy?

110. What is meant by and what is the effect of: underexposure, overexposure?

111. What is meant by and what is the effect of: underpenetration, overpenetration?

112. What governs the choice of film holder for a given x-ray?

113. Which type of film holder is "faster" and why?

114. Discuss the use of cones.